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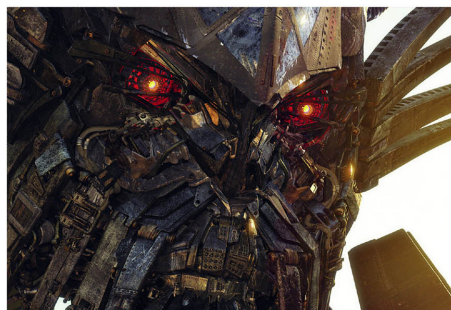
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Animal Action

ARTICLE BY JOE FORDHAM

Two large camera cases sat in the corner of Hoyt Yeatman's office at Jerry Bruckheimer Productions. image

One was packed full of computer hardware and another contained an ominous black cube, one foot square, made of gleaming carbon fiber with a red anodized metal lens cap on four of its surfaces. The gizmo and its controller were the Mark III version of Yeatman's HDR-Cam, an automated super-high-definition image acquisition device, conceived to assist digital artists in the reconstruction of high fidelity lighting environments, so far used on eight feature films including Yeatman's directorial debut, Walt Disney Pictures' talking guinea pig adventure, *G-Force*.

HDR-Cam was just one of many innovations conceived during the lengthy development of *G-Force*, evidence of Yeatman's passion for gadgetry and invention. "HDR-Cam sees 20 stops of dynamic range," Yeatman explained. "It sees well beyond the range of film, and is so powerful it can resolve the dynamic range of a 20K lamp, from the glowing element of the fresnel all the way to the darkest part of the shot. The operator can drop it into an environment, from as bright as a desert to as dark as a cave, hit the button, and in 30 seconds it acquires all the lighting information. The HDR processor puts it all in neat folders, with scene numbers, and automatically stitches it together. The CG artist gets the data, puts lights in the right place, with the correct 32-bit values, and in a matter of minutes can light a scene using discreet lights. It's not just 'image based lighting.' It's a fantastic tool for directors of photography, because it allows them to participate in the virtual world, lighting CG characters with lighting from the set. We used it in all our shots on *G-Force*."

After a career in visual effects and an Academy Award, Hoyt Yeatman's inspiration for *G-Force* came from his son, then aged five, who brought home his preschool class pet guinea pig — a brown and white satin American cavy — and concocted an imaginary adventure about the furry animal wearing a G.I. Joe-style helmet and backpack. Intrigued, Yeatman researched government experiments with animal intelligence and, together with his creative collaborator David James, devised a 30-page treatment that would become the basis of a screen story.

In that story, Darwin (voiced by Sam Rockwell) is the leader of a group of talking guinea pigs equipped with miniaturized spy gear, reared by the FBI to carry out covert missions. Demobilized and deposited to a pet store, the *G-Force* team — including Darwin, Juarez (Penélope Cruz), Blaster (Tracy Morgan) and a star-nosed mole named Speckles (Nicolas Cage) — meets a domesticated guinea pig named Hurley (Jon Favreau) and a grouchy hamster, Bucky (Steve Buscemi). The animals band together to combat a robot revolution masterminded by megalomaniac household appliance king Leonard Saber (Bill Nighy).

To market the project to potential studios, Yeatman spent a year creating a one-minute teaser trailer, filmed in high-definition and featuring digitally animated guinea pigs generated at his own production company in Burbank. The teaser and a mockup one-sheet poster attracted the interest of producer Jerry Bruckheimer. "I had worked with Jerry Bruckheimer on *Kangaroo Jack*," Yeatman

said, “which was his introduction to animation. By the end of that project, he saw the power an animated character could bring. I think that’s why he expressed interest in *G-Force*. He was excited to tell stories in a way that combined all the tools that we had as visual effects artists.”

While *G-Force* took shape with teams of writers, Yeatman developed characters and visualized the story with storyboard artists. At the same time, Persistence of Vision Digital Entertainment, The Third Floor and an in-house team of previsualization artists prepared 3D animatics of specific action sequences. Sony Pictures Imageworks visual effects supervisor Scott Stokdyk and animation supervisor Troy Saliba then joined Yeatman to brainstorm techniques for realizing animated animal characters.

Imageworks rebuilt characters from the ground up, working from conceptual art by Allen Battino and anatomical studies of real guinea pigs. Troy Saliba’s team modified guinea pig faces, locating eyes slightly forward on the snout to assist composition of closeups, and adjusted guinea pig fingers by using the fourth digit as an opposable thumb, allowing creatures to grip objects. With that exception, the creature team avoided anthropomorphizing the animals, and preserved the floppiness and vulnerability of guinea pig anatomy to comedic effect. “Troy and I both felt that it would be much funnier to see realistic-looking guinea pigs playing huge stunts,” said Scott Stokdyk. “Part of the appeal of a guinea pig is that they often look like cute little potato sacks. When their legs pull in, a lot of the definition of the leg disappears under their big sack of skin and they become a blobby mound. Troy worked all of those characteristics into the models and the rigging.”

Though animators had procedural tools at their disposal, they sculpted in much of the character dynamics by hand. Fur simulations also played a key role in defining the fluffy characters. “The guinea pigs’ hair made up a big part of their shape,” noted Stokdyk. “Each character had an underlying guinea pig volume, and that was central to the performance. After it went out of the character animator’s hands, our hair team added wind buffeting the fur, twitching whiskers, or follow-through dynamics as a guinea pig would land.”

Guinea pig performances were based entirely on keyframe animation. “I never once thought about using motion capture,” said Hoyt Yeatman. “I didn’t want the characters to look like humans in guinea pig suits. I always saw it as pure keyframe animation from talented animators. But there is something about motion capture that I think is very valuable, which is that it brings the cast together in one performance. One of the most difficult things about an animated film is creating a holistic performance out of all the little pieces.” As with most animated features, voice actors recorded their roles separately — with the exception of one session with Sam Rockwell and Jon Favreau working together. “That was gold, because they began to riff in a way that breathed life into the characters.”



Juarez, Darwin and Blaster – the guinea pig heroes of G-Force – sprang from the imagination of director Hoyt Yeatman, inspired by stories concocted by his then five-year-old son. The concept of talking rodent agents, equipped with miniaturized surveillance and crime-fighting gear, came to cinematic life with the backing of producer Jerry Bruckheimer, for whom Yeatman had worked previously in the role of visual effects supervisor. Sony Pictures Imageworks signed on to impart the live-

action family comedy with digitally animated creatures and visual effects generated in stereoscopic 3D.

Before shooting, Yeatman, Stokdyk and Saliba reviewed scenes as represented by storyboards and animatics, edited to temporary audio tracks. This was followed by animation 'kick-off' sessions that involved discussing character motivations in preparation for live-action plate photography. Yeatman used rigid puppets on set to pantomime animated action and define the space that characters occupied for lighting, grip and camera reference. During plate photography, a voice actor delivered talking animal lines from off-camera, providing temporary voice cues to assist with timings and actor interactions.

Imageworks then gathered HDR-Cam and motion picture reference of camera setups. "Director of photography Bojan Bazelli had a unique lighting philosophy," observed Scott Stokdyk. "He over-exposed and pull-processed the plates, which made great use of the high dynamic range of the film, maximizing the usable stops of exposure. We made sure wherever possible to get reference on film of how he lit the scenes, even if we knew we were going to re-create most of the environment in CG. And Hoyt's HDR-Cam was fast and easy to use. It got us consistent and reliable HDR images that fit seamlessly into our lighting pipeline. It was a great road map for us."

To allow camera access in tight quarters occupied by tiny animated characters, Bojan Bazelli favored compact motion picture camera bodies, including the Arri 235 for non-dialogue scenes, which was capable of filming up to 75 frames per second for slow-motion action. The grip and camera department rigged ingenious devices to place the camera at guinea pig eye-level. "Bojan used some very bizarre looking camera rigs," said Yeatman. "They were the funniest things, from little bitty skateboard-wheel concepts, to bungee-cams hanging off of wheelchairs, to dollies that had no wheels, inside of tires — we did everything we could to put the audience in unusual places."

For scenes in which actors would be lifting or holding animated characters, animal trainer Larry Madrid provided live guinea pig performers, which motivated realistic body language as human performers cradled the squirming animals, and provided in-camera reference for guinea pig body and fur dynamics. For scenes requiring actors to place spy gizmos onto guinea pig characters, the production created practical 3D resin props, derived from CG models. Imageworks then replaced props with digitally rendered counterparts that could interact with digital fur simulations.

Extended scenes of animated characters in contained environments required an alternate approach to traditional plate photography. "We had approximately 200 shots of animals inside a pet store terrarium," related Scott Stokdyk. "For that sequence, and a few others, we knew the purpose of the live-action shoot was to get good reference to



In training, Darwin displays his motor skills by riding a motion simulator. The creature design team based Darwin, the rodent team leader, on anatomical studies of

match the background. It was like a reverse of the movie 300, where they had actors on bluescreen; we used live-action plates as backgrounds and created all the texture and realism as CG synthetic foregrounds. That gave us complete control over camera placement and interactions with the environment.” For the terrarium scene — where the G-Force team members meet pet store inhabitants — Imageworks shot pan-and-tile backgrounds using General Lift’s motion controlled Tesselator rig, which precisely captured nodal moving background tiles.

To frame shots in real time, Imageworks employed its virtual camera system — developed for *Beowulf* — either handheld or using its pan and tilt mechanism. “It was almost like a digital scout,” noted Yeatman. “That gave us blocking, lensing, composition and A-to-B movement of the characters. We cut the scenes together to make sure they were working, and then the shots went to animation.”

The separation of foreground and background layers in animated scenes gave Imageworks the flexibility to embrace another technical challenge: pre-senting the film in stereoscopic 3D, an idea Disney first suggested during preproduction. Pace Fusion 3D in Burbank allowed Yeatman to test sophisticated stereo digital camera rigs developed for James Cameron’s documentaries and upcoming science fiction epic, *Avatar*. The equipment, although impressive, posed challenges for guinea-pig-scale shooting. “We couldn’t get the camera down to four inches off the ground,” said Yeatman. “That was a problem because we had a chase sequence following nine-inch-tall characters with a snorkel lens. I also talked to my good friend Eric Brevig, who was working on *Journey to the Center of the Earth*. His setup was different than what we needed, again, because it involved actors in greenscreen and bluescreen environments, which gave him more control over 3D effects.”

When Disney committed to a 3D presentation halfway through principal photography, Yeatman conferred with Scott Stokdyk and Imageworks 3D visual effects supervisor Rob Engle, and elected to generate 3D during postproduction. “We decided to make two movies that would work both in 2D and 3D,” explained Yeatman. “Handling 3D in postproduction allowed me to do away with all the technicalities of 3D on set. Dealing with that in the field — setting the interocular and convergence of the 3D lenses — would have been crazy, because even if you think you know how the shots go together during shooting, they often get rearranged and it can cause problems if a cut doesn’t work. Putting the 3D process into post gave us the ability to accentuate the depth of a character’s snout, or

real guinea pigs, copying Yeatman’s photographs of his son’s brown-and-white satin American cavy. Juárez sports a language decoder in her right ear, which translates guinea pig vocalizations to human speech. Though Imageworks mostly preserved natural rodent anatomy — retaining the creatures’ inherent floppiness and comic vulnerability — the artists made subtle alterations, adjusting eye positions and realigning digits to allow the animals to grip objects.



Speckles – a near-sighted, star-nosed mole – lends his navigational skills and sensitive nose for computer worms to the G-Force team. The production digitally modeled Speckles’ miniature spy gadgets, and made resin outputs for a stuffed dummy model of the mole to wield on set.

push it back in real time to see how it played in a cut. Rob Engle then crafted 3D like a sound mixer, determining depth as we needed it.”

Engle and his team built on stereoscopic 3D processes that Imageworks had used on projects dating back to *The Polar Express*, and more recently on *Beowulf*. The stereoscopic interface was based on a Maya environment, viewed through polarized glasses, and used a green grid to indicate the position of the theater screen in relation to characters and objects in a scene. “The green grid gave us a common language about where things were with respect to the audience,” observed Engle. “The interface was not unlike a traditional CG tool that gave the artist an objective view of the viewing platform of a camera. The green grid defined the edges of the screen, and we used depth-measuring tools to determine what was ‘in’ and ‘out’ of that screen.”

Scott Stokdyk’s team developed visual effects independent of the 3D team, assembling and lighting up to 60 passes per character in Imageworks’ lighting tool, Katana. When assembling composites, digital effects supervisor Seth Maury favored volumetric rendered elements over 2D effects, giving Engle’s team the option of adding dimension to atmospheric phenomena. Stereo artists then analyzed each shot to determine depth. “During animation, we’d decide which parts of the background needed to be broken out as separate objects,” said Engle. “At that point we kicked off our rotoscope and depth layout process to build rough geometry that corresponded to objects in the scene. We isolated elements with roto, tracing objects by hand, and created stand-in geometry for where objects would appear in 3D space. We did all that without wearing 3D glasses. We then went into our stereo camera layout to set the ‘interaxial’ spacing between the right- and left-eye cameras, and convergence. That’s when we made the creative choices about how to play depth.”

Engle’s team used multiple camera rigs to isolate objects in the foreground, controlling spacing of right- and left-eye cameras to add depth and roundness to objects, and angling the convergence of the stereo lenses to control spatial depth in frame. “The more we separated the stereo cameras, the closer and rounder objects felt. We used convergence to push objects away from or toward us without changing that roundness. If we had a shot of a human and a guinea pig in the same plane and wanted to give the human more dimension, we’d isolate the human, use a wider interaxial spacing to give him more roundness, and then push him back so he had correct depth.”

The dexterity of the postproduction 3D process allowed Imageworks to create characters that appeared naturally dimensional, rather than like 2D cutout shapes. “If all we did was map objects onto flat objects,” said Engle, “everything would have looked like cardboard. To augment the 3D geometry, we used a variety of 2D techniques, including

Imageworks then employed the same geometry to create Mooch, a common housefly, provides aerial reconnaissance using thorax-mounted cameras that unfold in flight. Imageworks worked closely with Hoyt Yeatman to develop gadgetry for the animated insect, inspired by real-world military nanotechnology.



In their laboratory staging area, G-Force team members review a video feed from Mooch. Director of photography Bojan Bazelli over-exposed and under-processed the motion picture negative to maximize dynamic range of the image and allow for great latitude in exposure. Imageworks used film reference and imagery captured by Hoyt Yeatman’s HDR-Cam – an automated 360-degree super-high-definition image acquisition device – to digitally re-build lighting environments in 3D.

image warping. We'd isolate the middle of an object, give it a little warp independent of the edges, and that created a sense of roundness. We'd also 'roto-mate' characters to define faces and bodies, and then map the textures onto 3D shapes. That created a very realistic sense of depth."

Imageworks spent almost one and a half years developing tools and creating the stereoscopic effects for *G-Force*, analyzing every cut. Out of a total 1,861 shots and 82 minutes running time, Imageworks produced 1,287 shots, or 61 minutes of footage. For the remaining shots, In-Three handled the conversion of non-visual effects shots to 3D. Sassoon Film Design also handled approximately 50 3D shots, and Asylum Visual Effects contributed to more than 270 visual effects and computer graphic screen displays. Rob Engle oversaw stereo effects, working with all of the visual effects facilities to ensure a seamless 3D experience.

One of the most unusual uses of 3D in the film was born out of an experiment that Imageworks had toyed with on *Beowulf*. "We were trying to figure out ways to bring the action out into the audience," recalled Engle. "In one of our shots, the widescreen matte wasn't quite right and the action overlapped it, breaking the widescreen mask at the top and bottom of the frame. It looked as if we were looking through a floating window in 3D and we were bringing objects out into the audience." The effect went unused in *Beowulf*, but a poster of the 1952 3D movie *Bwana Devil*, depicting a lion leaping out of a movie theater screen, inspired Engle to explore the frame-busting technique for *G-Force*. The 3D team selected a scene featuring a pet store snake lunging at a member of the *G-Force*, the reptile's jaws striking its glass terrarium wall, breaking the edges of the 2.40:1 widescreen mask with a comedic splat.



After a G-Force mission disrupts an FBI operation, the rodent agents are stripped of their gadgets and deposited to a local pet store. Scenes inside the store terrarium introduced a new group of animal characters. To shoot backgrounds for the sequence, which included about 200 visual effects shots, Imageworks filmed motion control tiles of the pet store set utilizing General Lift's Tesselator rig. Artists then reconstructed backgrounds behind a digital re-creation of the terrarium interior. Yeatman used the studio's virtual camera system to establish compositions in real time, prior to keyframe animation.

The startling effect inspired Yeatman to add a number of shots that occasionally allowed 3D objects to overlap the perceived barriers of the theater screen. "I've made a large number of special venue films, so weird formats have always intrigued me," admitted Yeatman. "But it posed a problem: how to project it in the field? We worked with the Disney engineers and they came up with a process to give theater projectionists special framing charts to make sure the masking was correct in general theatrical release. When we knew that was achievable, we used it, hopefully, with good taste. I found it very effective for 3D 'wow,' in-the-audience's-face moments." Frame-breaking scenes included the lunging pet store snake, protruding guinea pig legs, wriggling cockroach antennae and shards of flying glass rendered into the black horizontal borders of the top and bottom of the frame.

Stereo effects added to the excitement of the film's action scenes, including a sequence in which the *G-Force* team rides an RDV — rapid deployment vehicle — composed of three interlocking motorized transparent spheres. The production created a non-functional RDV prop for reference on set in downtown Los Angeles, filming with stunt coordinator Kenny Bates and special effects

coordinator Stan Parks. Imageworks then generated the RDV digitally, with G-Force characters inside. To capture backgrounds for the chase, Pursuit Systems supplied an articulated crane mounted atop a modified Porsche Turbo Cayenne. “We tried to get real in-camera footage wherever we could,” commented Scott Stokdyk. “The Pursuit Systems camera could fly up above the cars, and get down very low. They also had insert cars with snorkel lenses that could get very close down to the ground, and electric go-karts that had camera rigs attached to them, rigged with a small remote-controlled camera.”

For closeups of characters in the moving RDV, the production captured fish-eye-lens perspectives racing along the street using an 8mm lens on a Vistavision camera mounted at guinea pig eye-level. Imageworks digitally unwrapped the moving footage and projected it on a virtual dome. “We used the Vista footage as a pseudo-virtual environment,” said Stokdyk. “That enabled us to create any camera move we wanted on the foreground objects, with correct perspectives whichever way we looked. We then added a CG road surface and CG undercarriage of a sports utility vehicle.”

The production used Pursuit Systems’ mobile crane to shoot backgrounds for Mooch, a G-Force housefly equipped with microscopic aerial surveillance devices. “We called those scenes ‘Moocharama,’” remarked Hoyt Yeatman. “The typical National Geographic approach to visualizing an insect in flight would be to focus on the eyes, and everything else would be out of focus. But I felt that Mooch, as a character, saw himself as large as a Cobra attack helicopter. He’s invincible! So we filmed that with a spherical fish-eye lens, and he appeared gigantic in frame. Then, when we cut back to a wide shot, we revealed he was this little teeny creature!”

In one of Mooch’s starring moments, the courageous fly infiltrates a cocktail party in Saber’s home, and barnstorms a waitress carrying a dessert tray. Imageworks generated a virtual environment for the sequence using an ingenious live-action plate shoot. “We put a fish-eye lens on a Vistavision camera shooting straight up in the air,” Yeatman explained. “The camera was on a little roller device, and the actress playing the waitress pushed it through the party as if she was carrying the tray. We unwrapped that footage and digitally projected it onto a virtual dome. That gave us a hemisphere of the party in motion in 360 degrees. Imageworks then added a computer graphics platter of desserts. We animated one continuous move flying right into it, entering the world of the cupcakes, with the party-goers moving all around. We did a lot of tricks like that, moving in and out of virtual environments, combining Scott’s expertise creating photoreal worlds in *Spider-Man* with animation by the Imageworks’ team from *Surf’s Up* — using the best of both techniques.”



Hurley – a flatulent, long-haired cavy – escapes the store with Darwin and rides piggy-back inside a motorized transparent sphere, part of the G-Force rapid deployment vehicle. To capture backgrounds for the RDV dodging obstacles on Los Angeles streets, the production employed an array of ingenious mobile camera rigs, including custom camera cars supplied by Pursuit Systems. For shots of the RDV passing beneath a sport utility vehicle, Imageworks used fish-eye-lens imagery taken by a camera skimming a road at guinea pig eye-level, digitally unwrapping the footage and projecting it onto a virtual dome.

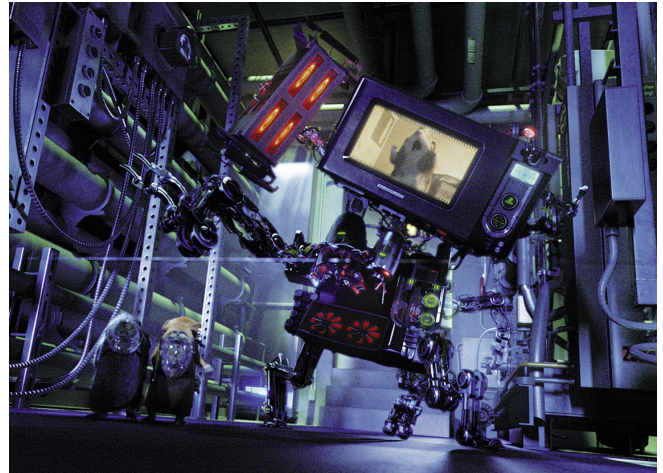
Imageworks also generated G-Force's adversaries, an army of marauding robots, which again had been inspired by Hoyt Yeatman's observation of his son. "He was at the age when all boys like dinosaurs and robots," Yeatman recalled. "I was watching him play, and started wondering what it would be like if we took everyday household appliances and brought them to life in a strange way that could be 'evil,' while maintaining their original look. There was a fine balance between making them scary and being clever about how we mechanized them, bringing them to life in clusters. We had Hurley captured by a combination of a microwave, cappuccino machine and a toaster!"

With the exception of a non-mobile replica of a crushed coffee machine, Imageworks digitally generated all robots based on production art and CAD designs. The animated agglomerations of appliances included an 85-foot-tall robotic tripod known as 'Clusterstorm.' "We did a lot of base-level modeling and rigging for all of Clusterstorm's components," Scott Stokdyk explained. "A combination of animators and layout artists then hand-animated individual parts to camera. We first animated base-level geometry, and then added dynamics. We had a special team that did nothing but cables. We had cables that wrapped around objects, cables that cinched together, swinging dynamic cables, cables that were attached on one end and loose on the other, bundles of cables and individual cables."

The finale of the film involves members of the G-Force team trapped inside Clusterstorm's mechanisms as the monster robot assembles itself around them. Imageworks fashioned the robotic interior as a dynamic virtual environment of moving machine parts. "The 3D build was incredibly huge," observed Stokdyk. "We pruned out pieces of the set where sections were off-screen and then pulled in a library of machine components to dress parts to camera shot to shot. It was a weird hybrid of dynamics, environment and character animation all rolled into one."

The action climax ends on an upbeat note, delivering a wholesome message to its intended youthful demographic. "Animation can be anything you want," declared Hoyt Yeatman. "In the United States, it's usually designed toward children; in France and Japan it's different. We tried to be careful with subject matter and the arc of the story so it had moments of intensity, but the kids were always in control and it had a positive resolution: Darwin believes at first he is genetically altered, only to find that he is not, so he has to believe in himself. It's about teamwork, achieving what appears to be the impossible. They were classic Disney themes; and that, to me, was exciting."

Yeatman's enthusiasm for the eccentric story proved infectious, particularly with the visual effects team with whom he shared a common language. "It was very easy for me to get inside Hoyt's head,"



Blaster and Darwin infiltrate the home of their nemesis, an evil genius intent on enslaving the world with invasive technology, where they are attacked by a robotic monster comprised of kitchen appliances, including a microwave oven in which Hurley is imprisoned. Imageworks generated robots based on production art and CAD designs, and then animated agglomerations of appliances. Modelers built mechanical creatures using component parts. After animators keyframed a base-level machine performance, dynamic simulations of cables and other mechanical artifacts were added.

Scott Stokdyk observed. “Hoyt has such an analytical mind, he had an explanation for how everything worked — all the spy gear, the equipment and nanotechnology. He was an amazing resource for how we textured those worlds. And when it came to reviewing shots, I found myself very much on the same wavelength. I would start to describe what I had planned to do for a shot, and he could finish my sentence. He was a great leader.”

The experience, for the new director, was essentially collaborative. “No one person makes a movie,” Yeatman emphasized. “It really was a collective group effort. It was a constant creative exploration, hitting at ideas every day, trying to tell a good story. I do hope to make another film. I have no idea what that will be, but I naturally gravitate toward the crazy and unusual. I’m a big kid at large. I have never grown up!”

G-Force photographs copyright © 2009 by Disney Entertainment. All rights reserved. Special thanks to Chrissy Woo, Tracy Kettler, Rachel Falikoff and Mike Johnson.

Slumdog Aliens

ARTICLE BY JOE FORDHAM

Neill Blomkamp's short films and television commercials have captured the imaginations of streaming video fans with images of fantastic technology run amuck in urban settings: a breakdancing Citroen car, crab-like soccer-playing robots, fugitive androids, Third World robot militia and a heartsick secretarial office drone. "I always like to present the fantastic or the unreal in an environment that is completely real," observed Blomkamp. "It's just something that I find appealing, even if I am not aware of it."

Blomkamp's best-known short, *Alive in Joburg*, was an independently financed production, shot between Blomkamp's commercial assignments. The six-minute faux news report intercut interviews of Johannesburg inhabitants with newsreel-style footage of a ghetto containing refugees of an extraterrestrial civilization. "I took a Western science fiction concept and placed that in a Third World African setting in the city where I grew up," explained Blomkamp. "I hadn't seen those two things mixed together before, and when I started experimenting with that imagery, it really resonated." The short film's disturbing images of downtrodden tentacle-faced creatures, a marauding robot and enormous hovering spaceships spread like wildfire on video-sharing websites and catapulted the young director into the Hollywood limelight. Universal Studios president of production Mary Parent invited Blomkamp to meet with filmmaker Peter Jackson, whose Wingnut Films was developing a movie based on Microsoft Game Studios' sci-fi computer game, *Halo*.

Blomkamp flew from his home in Canada to New Zealand, and instantly clicked with Jackson's creative team. But after five months' preproduction, funding collapsed and *Halo* ground to a halt. "I was getting ready to move back to Vancouver," Blomkamp recalled. "Peter's wife Fran Walsh said: 'Why don't you just stay? Let's start something else that's not a studio film.' *Alive in Joburg* seemed like a

image



An alien mothership hovers over Johannesburg in a Weta Digital shot produced for District 9. Co-written and directed by Neill Blomkamp – making his feature debut after a career in commercials and shorts – the film used a documentary shooting style to depict aliens as downtrodden beings living in harsh ghetto conditions. A native South African, Blomkamp developed visual concepts at producer Peter Jackson's Wingnut Films, working with Weta Workshop, and then brought a majority of the visual effects work back to his current hometown of Vancouver, where Image Engine and The Embassy generated the aliens and their technology.



Officials from Multi-National United – a terrestrial technology consortium – interrogate an alien in a scene created for the teaser trailer. Blomkamp worked with creature development teams at Weta Workshop and

good diving-off point. We dusted that off and reconfigured the story into District 9.”

The screenplay by Blomkamp and Terri Tatchell begins, like its short film predecessor, with alien visitors living in District 9, a ghetto beneath their spaceship on the outskirts of Johannesburg, where they have been harbored for 20 years. Documentary-style establishing scenes then interweave a more conventional narrative that follows Wikus van der Merwe (Sharlto Copley), an employee of Multi-National United — a terrestrial technology consortium — who develops sympathies for the aliens through his contact with alien Christopher Johnson (Jason Cope).

Image Engine to concoct an alien design that challenged genre conventions, depicting the creatures as bizarre, yet sympathetic specimens of an insect-like ecology. Creature performer Jason Cope played alien roles on set wearing a gray-colored tracking marker suit. Image Engine digitally erased Cope from plates and studied his performance as reference for rotomation and keyframe animation of the digital characters.

Weta Workshop worked with Blomkamp to design the aliens and their technology, exploring conceptual designs and options for shooting on location with a relatively small budget, in the post-apartheid Johannesburg slums. “I first thought we were going to have to do alien characters as in-camera prosthetics,” Blomkamp commented. “It didn’t look like we were going to be able to afford to create the number of aliens that we needed digitally. As it turned out, we used almost entirely digital aliens, which meant there were no prosthetic or suit limitations to the way we shot them. We started playing with the idea that the aliens were an insect-like ecology. I worked with David Meng, a conceptual designer and sculptor at Weta, and he fleshed out the design to create this extremely wiry and gross-looking creature, something you wouldn’t want to sit next to on the bus.”

The alien took shape as a maquette representing a scrawny insect biped with backward-bent legs. Weta Workshop built prosthetic parts to represent dissected creature limbs. For creature scenes, the production planned to shoot Jason Cope on set, wearing a gray pajama-type suit with tracking markers, interacting with human characters. Visual effects would later use Cope’s performance as the basis for computer generated aliens.

As Blomkamp drew up plans for a location shoot in Johannesburg, the workload at Weta Digital increased on its current projects, including James Cameron’s science fiction epic *Avatar*, and it became clear the production would have to look elsewhere for its primary visual effects vendor. Image Engine visual effects executive producer Shawn Walsh and digital production supervisor Peter Muyzers leapt at the opportunity. “We’d seen *Alive in Joburg* on YouTube,” said Peter Muyzers. “We knew Neill had been a visual effects artist, like us, in Vancouver, and we’d been following his work. We also knew he was trying to do a feature with not a lot of budget, shopping it around in Vancouver because Weta Digital was busy. We were very interested in that opportunity.”

Image Engine inherited the lion’s share of visual effects, including alien characters and establishing shots of their mothership and military hardware. Muyzers was joined on location in South Africa by representatives from The Embassy, who had worked on many of Blomkamp’s commercials, and who mainly handled a third-act action sequence. During post, visual effects production manager Marie-Cecile Dahan joined the team, along with Weta Digital, which returned to assist as the shot count grew. Zoic Studios handled overflow 2D work, and Goldtooth Creative generated alien holographic displays.

The production staged two shoots in Kliptown, one of the poorest townships of Soweto, and a one-week interior soundstage shoot in New Zealand. To secure a safe area for location shooting in South Africa, production manager Philip Ivey made use of a shantytown region that local authorities were in the process of transforming into a green space, relocating inhabitants to housing elsewhere in the region.

Shooting conditions were chaotic. “It was insanity,” said Neill Blomkamp. “Jason Cope actually played every alien. In a scene where MNU was evicting aliens from their shacks, we went from one shack to the next, and Jason played a different alien each time, in real time, interacting with our human characters. We then had to rotomate him and paint him out from the handheld footage, and track and add animated characters. It was an intense amount of paint-out and plate restoration work, and the visual effects guys were running and gunning, trying to figure it all out as I was shooting. The whole thing was improv.”

The dynamic nature of the shoot made it impossible to place on-set tracking markers, or use witness camera systems to record performer reference on set. “We tried some tests with witness camera technology,” said Peter Muyzers. “The problem was, if we placed witness cameras on set, and then Neill wanted to swing his camera around, we’d have had to keep moving out of the way. It was too restrictive. We had to wing it, and we ended up capturing the motion of the gray-suit actor just from production footage.”

Data wranglers took measurements, and captured lidar scans and high dynamic range images as often as possible on set. Image Engine visual effects supervisor Dan Kaufman then led the charge in postproduction, working with matchmove lead Derek Stevenson to handle tracking using combinations of The Pixel Farm’s PFTrack, 2d3 boujou and Science-D-Visions 3D Equalizer. Image Engine also outsourced complex tracks to Yannix Technologies. “We tried to give Neill all the freedom he needed in shooting,” Dan Kaufman noted. “But we did mention to him that zooming complicated



Weta Workshop sculptors Sean Foot, Antony McMullen and Steve Boyle work on a full-size clay maquette of lead alien Christopher Johnson, a character who stood nine feet tall on backward-bent insect legs, defying human anatomy. The completed sculpture became the basis for Image Engine’s library of digital alien assets, from which the team created aliens of all ages, shapes and sizes, clad in strange combinations of terrestrial clothing.



Weta Workshop also created a series of foam latex prosthetic makeups depicting the effects of an alien

the tracking and lens curvature correction. The interplay of different lenses moving in relationship to each other dynamically changes the distortion of the image. Yannix has its own technology for calculating that on a frame-by-frame basis.”

infection that deforms the film’s human protagonist. Weta artist Dordi Moen airbrushes alien torso appliances.

To give the human actors correct eye-lines with aliens towering over them, Jason Cope wore height-enhancing prosthetics. “Some of the aliens, including Christopher Johnson, were seven feet tall,” observed Image Engine animation supervisor Steve Nichols. “Jason strapped on stilts for some of those scenes. Other times, he wore strange little eye-line cups that hovered above his head, which the other actors could use as a reference. The problem with the stilts was sometimes the performance came across as exactly that — a guy on stilts. Neill picked up on that right away; and so we wound up animating a lot of those scenes keyframe.”



Weta Workshop artist Shari Finn works on a prototype prop representing a mechanical alien exosuit, a powerful bipedal battle machine worn by an alien operator.

Alien animation began with studies of Weta's conceptual designs, accompanied by nature research. "The main thing Neill wanted was realism," stated Image Engine creature supervisor James Stewart. "He wanted to take every possible reference that exists in real life and build it into the characters. We looked at cockroaches, dung beetles, goliath bugs. We worked with a fantastic nature photographer and processed his pictures at high resolution, then used those textures to get into the crevices of how insects articulated."

Image Engine developed an alien model as rigid interlocking body parts with flexible sinewy joints, exoskeleton shell, binocular eyes and a muzzle full of tentacles. "Neill wanted us to feel compassion for these characters," observed Steve Nichols. "We gave them very articulate faces. The upper part of the face had expressive eyes and brows; and then the lower half, from the nose area to the mouth, was made up of tentacles. By having tentacles partially obscure the face, viewers impart their own interpretations into the performance."

The aliens' bizarre facial articulation played a crucial part in evoking empathy for the stranded, tragic creatures. "One of the things that I was wrestling with," declared Neill Blomkamp, "and I think I am going to continue to wrestle with for the rest of my career, is that Hollywood movies tend to simplify ideas. I wanted to create a completely alien creature. But the only way, in Hollywood, you can present a creature as completely alien is if it is a formidable force — as Giger did in Ridley Scott's *Alien*. For any form of sentient being that the audience has to relate to, our psychology seems to require aliens to be presented with a human face. It really bothered me that I had to do that. In the end, we came up with a design that was hard-shelled, like an insect, but it had the ability to emote by configuring its face into recognizable emotional shapes."

"The base structure of the alien face mimicked a human face," added James Stewart. "It was essentially a crab-like shell; but if you put a skin over the top and had the shells drive that skin, it looked very human." The creature team rigged alien physiognomy using keyframe blend shapes of endoskeleton structures, combined with fleshy tentacles containing skel-et al structures and dynamic muscle simulations.

For crowd scenes — with aliens of all ages, shapes and sizes attempting to blend into human society by wearing strange conglomerations of clothing — Image Engine research and development lead John Haddon and asset lead Nigel Denton-Howes assembled a library of alien parts. "We created hundreds of versions of alien characters based on only a couple of designs," said Stewart.



Artist Johnny Brough attends to the paint job of an alien assault rifle with extended drum magazine, used in a fierce gun battle in the third act of the film. Working from concept art by Greg Broadmore, Weta Workshop designed and created a number of exotic alien weapons, which become a focus of attention for MNU as it attempts to exploit the alien technology.

“We could vary the size of the alien bodies, change paint schemes, dirt maps and clothing. We could select different paint splatters, stickers, travel markings, colors and textures. It created an amazing variety of textures that integrated into this very detailed environment.”



Using handheld digital cameras, Blomkamp shot much of the film on location in Soweto, where the employment of traditional visual effects set surveys, tracking markers and witness cameras was unfeasible. Instead, representatives of Image Engine and The Embassy recorded location data wherever possible, and then relied on postproduction tracking solutions to place digital elements such as the floating mothership, military vehicles and helicopters.



MNU representative Wikus van der Merwe (Sharlto Copley) confronts an aggressive alien who takes exception to being evicted from his ghetto home. Image Engine digitally generated the alien based on photography of Jason Cope.

To animate the creatures, Image Engine used rotoscoped animation of Jason Cope's performance, keyframe animation and occasional motion capture. Keyframe and motion capture also figured into the animation of a smaller character — Christopher Johnson's three-foot-tall son, 'Little CJ.' "We motion captured Peter Muzer's son," said Dan Kaufman. "That got us some information for Little CJ's movement. We then modified that to add more segments to his legs." The majority of Little CJ scenes employed purely keyframe animation, including a moment in which the feisty youngster displays feral tendencies, attacking and biting Wikus.

Blomkamp shot the majority of plates using the RED camera system, but also made use of Sony EX1 high definition prosumer cameras and analog video stock footage. "The South Africa Broadcasting Company provided archive footage of rioting," Kaufman said. "In a handful of those shots, Neill asked us to add aliens and sometimes replace people with aliens. It was very low-rez, and we had no camera information. We calculated the lenses, created matchmove geometry, tracked in aliens, did paint-outs where needed, and then degraded the image to shoehorn in our characters."

The Embassy integrated into plates a smaller breed of creature, an alien pet that was a cross between a scorpion and a crab with tentacles in its mouth. "It was hard-surfaced, like a crab," said The Embassy lead technical director Matthew Rouleau, "and it scuttled around pretty fast. We keyframe-animated them and rendered them with reflections, specular maps, diffusion and subsurface scattering to make their shells translucent. They were aggressive little creatures; and at one point we had one ripping off a guy's face. We rebuilt the actor's face with skin and flapping bits, did camera projections onto the CG model and animated him to move as the creature was biting him."

One of the film's most dramatic sequences had MNU officers brutalizing Christopher Johnson with a baton. "We shot a couple of takes with Jason wearing his gray suit," stated Peter Muzers. "Then the MNU performers really went to town, beating a stuntman dressed in the gray suit, wearing a protective vest."



Christopher Johnson peers out the window of an armored personnel carrier, before being interrogated and brutally beaten. Alien facial structures included a segmented carapace, articulated mandibles and fleshy tentacles that hung from the nasal area. Animators articulated rigid portions of the alien face, and controlled tentacles using skeletal structures and dynamic muscle simulations.



For the trailer's interrogation scene, Jason Cope played the interrogator in addition to performing Christopher Johnson's interactions.

Animators used rotomation of Cope and the stunt performer with keyframe adjustments. “In our first pass, we matched what was done by the actor,” Steve Nichols explained. “We then ‘insecticized’ it, adding tweaks and twitches to make the character’s motions more razor-sharp and alien, while retaining the performance. Each time Neill saw a take, he asked us to amp up the impacts. The harder we hit CJ, the more Neill liked the shot. I can’t remember seeing a digital performer getting the crap beat out of him this way before. He was bleeding, coughing up blood and saliva — it was intense.”



Smaller creatures – known as ‘alien pets’ – are pitted against each other, as in a cockfight, and forced to fight for survival in the brutal environment of District 9. Far from friendly, the pets are aggressive carnivores capable of rending human flesh with their claws. Artists at The Embassy modeled the alien pets as hard-surfaced arthropods, with segmented scorpion-like bodies and fleshy tentacles around their mouths, and keyframe animated them with fast scuttling motions. Alien pet surfaces were rendered with reflections, specularity and subsurface scattering to simulate translucent shells.

To create the aliens’ mothership, Image Engine referenced Weta Workshop conceptual art of the ship, which resembled an enormous inverted industrial refinery. “The spaceship was supposed to be about two and a half kilometers in diameter,” Dan Kaufman noted. “It had tons of detail, which was very hard to create at that scale. We achieved that by modeling the piping at a bigger scale, and then using cards and tons of texture reference of real industrial buildings to beef it up to a finer scale.”

For shots of MNU and television news helicopters hovering around the enormous floating disc, the production leased helicopters from a South African mining contractor. Image Engine then generated three makes of digital helicopter to supplement the practical aircraft, and added MNU logos. Image Engine also modeled and replicated fleets of Casspir armored personnel carriers, then added digital doubles of MNU infantrymen.

Weta Digital took on mothership shots that did not include aliens. Image Engine supplied Weta with its mothership model and textures; Weta retooled the model for its internal pipeline and enhanced detail for scenes hovering close to the enormous space vehicle. “We packed a huge amount of geometry into the shots,” commented Weta Digital visual effects supervisor Matt Aitken. “We did a lot of modeling with curves, and used real-world-based textures with rust and corrosion. We dug out the weathering tool that we had developed for New York City in *King Kong*. That was a particle-based solution, which acknowledged the geometry of objects, and created running streaks quite nicely.”

The production filmed mothership interiors on soundstage sets, including reference for a shot — added in the last month of postproduction — that reveals the mothership’s hold teeming with alien refugees. Blomkamp shot Jason Cope in gray suit scrambling through debris, and that element became the basis for choreography of the shot. “Neill liked the reference so much,” said Dan Kaufman, “he asked if we could put the alien in where Jason was scrambling. So we started with that, and then tilted up to a 2½D environment that involved a background matte painting that Weta created. We added foreground set extensions and all the aliens.” Limited time to complete the one-off epic shot meant complex artificial intelligence crowd simulations were unfeasible. Instead,

Image Engine layered animation rotomated from Cope's performance with keyframe and motion captured midground aliens, and animated motion cycles projected onto cards for background aliens. Compositors layered the shot in The Foundry's Nuke and illuminated characters with bonfires and flashlights scattered through the environment.

MNU reconnaissance of alien technology also reveals a smaller alien space vehicle, the size of a large bus, which The Embassy generated as a 3D model and Weta Digital integrated into shots. "The dropship first appeared in an early documentary montage of the mothership," recalled Matt Aitken. "We did another version of that shot where the footage is forensically analyzed and the dropship is seen in the corner of the frame, dropping out of the mothership. Wikus then locates where the ship has been hidden and fires it up — which was our biggest single task on the show."

For Wikus' dropship flight — which starts with the craft bursting free of a hiding place under Christopher Johnson's home — the production shot background plates around the shack in Soweto. Weta Digital then created digital erupting effects. "It was a very complex simulation," observed Aitken. "We wanted to avoid its looking like a bunch of particle effects obscured by dust, because we felt that people are getting used to those visual sleights of hand." Blomkamp referred Aitken to reference footage of an Iraqi improvised explosive device. "The IED had been buried too deep and, as an Army truck drove past, the ground heaved, forming a giant mound. That was crucial reference for how the dropship displaced the earth and destroyed the shack. We then had an aerial plate that Neill shot from a helicopter, and we added the dropship breaking free. A lot of simulation work and very complex compositing went into that. We generated all the elements digitally because we would never have been able to control the performance if we had tried to shoot them practically."

After crashing the dropship, Wikus commandeers a large alien mechanical exoskeleton and seeks to use the robotic suit to shoot his way through an MNU defensive line. Weta initiated 'exo' designs, modeling and previsualizations, and The Embassy then developed the animated character. Embassy president Winston Helgason attended the first round of photography of exo scenes in Soweto, for which Weta Workshop created a full-sized static prop. A second round was accompanied by Embassy visual effects supervisor Bob Habros. "We approximated exo's height on set using a pole with a piece of tape for eye-lines," explained Habros. "It was often in shots that involved aliens, so we usually shot a rehearsal take with the gray suit to help get the proximity and a spatial understanding of where the characters were going to be. Then we either shot the gray suit for the alien, or nothing at all."



A key scene involves a large mechanical exoskeleton that Wikus commandeers and uses to breach a defensive MNU line. Weta Workshop developed designs for the alien exosuit and built a full-scale prototype. Weta Digital created a CG model and previsualization for the action. A late design change streamlined the exosuit, which The Embassy realized as a digital character. To shoot scenes of the exosuit on location in Soweto, Embassy representatives gauged the giant biped's height on set by using a pole.

By that second round of shooting, the character's design had evolved considerably, becoming more streamlined to allow for nimble action. The Embassy adapted the revised exo design, working from Weta Digital's model. "Weta provided us with an OBJ-file model," related Matt Rouleau. "We used that to create a hard-surface jointed character with working pistons and wires. We added rubbery sections in the neck, and rigging to get all the joints and pistons interacting." As texture reference, Blomkamp supplied The Embassy with replica guns to illustrate an alien alloy sheen. "Neill liked different chromes and metal finishes on the replica guns. We settled on a diffuse black powder coat as the primary surface, with accents of chrome and brass."

To simulate MNU and exo gunfire exchange on set, special effects supervisor Max Poolman supplied practical pyrotechnics in Soweto. The Embassy then developed animated armament. "Exo had anti-gravity function, missiles, a rail gun, and an arc gun," explained Bob Habros. "We researched and developed the look of each of those effects. The physical effects team did a fantastic job with interactive effects on set; then, whatever we didn't achieve on set we did in CG so we could direct the interaction." As the shootout progressed, the exosuit received heavy damage, requiring a succession of alternate model builds and weathering effects to suggest bullet hits and dirt and grime. "At one point his arm got blown off, and there was some damage to his front panels. We ended up creating six versions of the suit, which we matched from shot to shot."

The Embassy used Andersson Technologies SythEyes to handle tracking of the robot into chaotic handheld plates, and integrated a practical element of a pig carcass hurled through frame, which exo used as an improvised projectile. Vancouver special effects coordinator David Barkes supplied additional pyrotechnic elements including propane balls, bullet hits, blood splats, and a 'meat bag' explosion that The Embassy integrated with an exploding pig carcass effect that Max Poolman's team rigged in Soweto.

Closeups of Wikus inside the exosuit had Sharlto Copley seated in a full-size mockup of the exo interior filmed in New Zealand. Weta Digital enhanced the shots with animated graphics projected in spherical 3D space around the actor as an alien heads-up display. Copley also performed motion reference in New Zealand, providing The Embassy with exo's body language. "As the design changed," noted Habros, "the idea of exo's performance changed, from very tank-like and mechanical to more about the character. Neill wanted the audience to understand it was Wikus in the suit, so we gave exo an attitude reminiscent of the actor." For shots of MNU gunfire tearing into



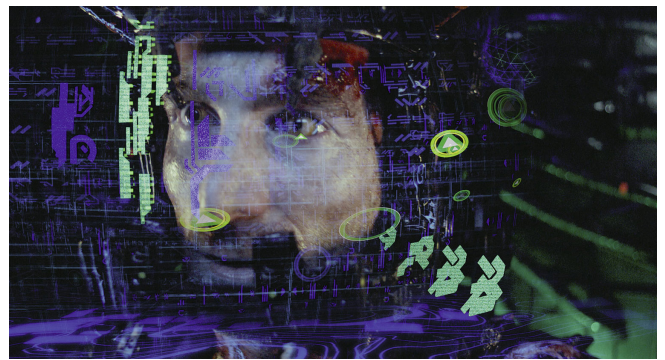
The final suit design incorporated elaborate weaponry, which Wikus uses to repel fusillades of gunfire. Special effects supervisor Max Poolman supplied practical pyrotechnic and gore effects in Soweto. The Embassy then generated digital simulations of exploding exosuit panels, bullet hits and battle damage. Sharlto Copley performed motion capture reference, which The Embassy employed to guide the exo's body language and re-create Wikus' gait in the machine. Compositors blended the animated character with practical pyro and blood effects furnished by Vancouver special effects coordinator David Barkes.

the suit, causing Wikus to tumble out, the production shot Copley falling to the ground on location in Soweto and then tracked the actor into the animated exo as its mechanical functions expired.

As the finale plays out, the long dormant mothership reawakens. “We animated the ship rotating,” said Matt Aitken. “As its engines turned on, a giant shockwave spread out across the environment. We had a wide shot of all the skyscrapers in downtown Johannesburg, their windows shattered. We had wide shots of the city where resonant energy from the mothership sent power wires swinging, dust storms swirling, and foliage blowing as if it was in a hurricane. That involved a lot of particle simulations, rendered elements and compositing, building up layers of effects.” The alien vessel rises skyward, seen from ground-level handheld camera perspectives. Blomkamp urged Weta to avoid overtly animated effects in the mothership’s engines. “Neill never wanted us to go ostentatiously sci-fi with any of the effects. For the thrusters, we tried to convey an effect of a massive force that could lift this giant ship up into space, but we also kept it quite subtle. It had a very gritty sensibility.”

The high volume of effects work — more than 500 shots, including approximately 35 minutes of character animation — was made possible by close collaboration with a filmmaker well versed in the capabilities of digital filmmaking tools. “When we started on the show,” Peter Muyzers recalled, “we knew that Neill knew a lot about visual effects, so we asked him outright: ‘How much do you want to get in there and tell us how to do it?’ He said: ‘Guys, it’s your thing. If you tell me that this is the best way, then we’ll go ahead and do that.’ Of course, working with a director that knows a lot about visual effects, you can’t get away with anything! But it was good to work with somebody who knew what he wanted and understood the boundaries of effects.”

The dexterous use of digital technology allowed the production to bring a visceral and imaginative sensibility to a staple of the science fiction genre. “There is a generation of filmmakers emerging now that is tired of seeing the kinds of visual effects we were exposed to in the late 1990s and the early part of this decade,” asserted Neill Blomkamp. “CG just got out of control. It wasn’t being created for the right reasons. It was bullshit spectacle. I think we’re going to see filmmakers reverting back to using effects in ways that can amplify the texture of the film, not diminish it.”



Wikus pilots the giant exosuit. Sharlto Copley performed suit interiors inside a full-size prop on a soundstage in New Zealand. Weta Digital created a heads-up display to surround the performer with animated readouts projected in spherical 3D space, generating layers of graphics in an alien language that described an array of nonterrestrial technology. Weta projected the graphics onto spheres of geometry around Wikus’ head.

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Military Maneuvers

ARTICLE BY JODY DUNCAN

In 1982, toy giant Hasbro relaunched a military action figure it had introduced in 1964. The new 'G.I. Joe' line of toys included all manner of military paraphernalia, props in a back story involving an ongoing struggle between the elite G.I. Joe Special Forces team and the malevolent Cobra organization.

image

Hasbro and entertainment-field collaborators extended and expanded the storyline in comics and animated television series. But Joe earned his highest rank yet when Paramount Pictures and director Stephen Sommers joined forces to create a glossy, energetic live-action feature film, *G.I. Joe: The Rise of Cobra*. In the movie, the feature film, *G.I. Joe: The Rise of Cobra*. In the movie, the G.I. Joe team takes on two new recruits, Duke (Channing Tatum) and Ripcord (Marlon Wayans), who have a personal stake in retrieving high-tech war-heads stolen by Cobra agents.

Sommers drafted visual effects supervisor Boyd Shermis and visual effects producer Rhonda Gunner a few months prior to the start of principal photography in February 2008. Also on set throughout much of production was visual effects supervisor Greg McMurry, who shot some first and second unit footage for specific visual effects sequences. Production crews filmed in Prague, Paris and Los Angeles; and then, in postproduction, McMurry, Shermis and Gunner oversaw 1,625 visual effects shots, spread among 10 visual effects houses — CIS Hollywood, Digital Domain, The Moving Picture Company, Frantic Films, CafeFX, Framestore, Pacific Title, Pixel Playground, Lola Visual Effects and Illusion Arts. An internal visual effects team, led by Joseph Grossberg, performed additional compositing and cleanup duties.

A prologue sequence begins with an establishing shot of a castle in 17th-century France. Frantic Films — now part of Prime Focus FX — digitally enhanced a real Prague castle with snowfall and smoke rising out of the chimney, and also contributed to a scene inside, where a man named McCullen (David Murray), convicted of conspiring against the crown,



G.I. Joe, Hasbro's 45-year-old military action figure, served as inspiration for director Stephen Sommers' G.I. Joe: The Rise of Cobra. In the film, an elite G.I. Joe Special Forces team combats the malevolent Cobra organization from its top-secret base, called 'the Pit,' buried deep within the Sahara Desert. CIS Hollywood – one of 10 visual effects facilities that worked on the film – extended a small live-action set to create the vast Pit interior. Visual effects supervisor Boyd Shermis and visual effects producer Rhonda Gunner oversaw the show's 1,625 effects shots.



MARS Industries – a high-tech weapons firm that has developed lethal nanomite technology – provides cover for Cobra's plans for world domination, masterminded by

is punished by having a burning hot iron helmet seared to his head. “The final shot when he gets the mask pinned onto his face had to be completely virtual,” explained Boyd Shermis, “because, after they’d shot it, they decided to change the whole camera move.”

MARS CEO James McCullen (Christopher Eccleston). In a CafeFX shot, McCullen appears to the G.I. Joes as a 3D laser-projected hologram to remotely inspect nanomite warheads under the military’s protection. To capture imagery for the hologram, Eccleston was shot in a separate pass on the set, with fluorescent tubes standing in for the light table to ensure lighting continuity. CafeFX rotoscoped McCullen back into the scene, along with laser projection beams and a flicker effect generated in 2D.

“We extended the shot so that it was 120 frames longer,” said Frantic Films visual effects supervisor Chris Bond, “and with a different camera move. At the moment they put the mask on the guy’s face, everything becomes synthetic — the character, the background and the mask, which was CG the entire time. For the eyes behind the mask, Mike Fink shot some eyes for us on stage, old-school.”

The film cuts to the ‘not too distant future,’ to the MARS Industries weapons complex in Kyrgyzstan, where the descendant of the 17th-century McCullen (Christopher Eccleston) introduces to military and government brass his company’s newest technology — microscopic robots, called nanomites, shown eating through tanks and city structures in a simulation produced by Frantic Films. Frantic and Digital Domain did early design work on nanomite swarms — which would be seen in destruction scenes throughout the film — and Sommers and Shermis used elements of both in the final concept.

For its nanomite simulation shots — as well as others in the film — Frantic Films generated billions of particles using proprietary tools. “We used Krakatoa, our particle rendering system, for rendering,” said Frantic visual effects co-supervisor Chris Harvey, “and then a lot of custom code and scripting for the behavior of the swarm. There had to be artificial intelligence written into the particles to suggest these billions of tiny robots devouring metal. They would swarm across a surface and attack it as a group, eating away the metal and then moving on to a new spot. We also designed a mechanism for eating geometry, creating the look of metal peeling away in flakes.” A greenish tint to the particle swarms made them look less like smoke or other natural phenomena.

After the demonstration, a military convoy that includes Duke and Ripcord transports four nanomite warheads in a case from the MARS facility. For a shot of two Apache helicopters taking off to escort the convoy, Framestore replaced a live background to make it look more remote. “We took a helicopter from where it was shot and stuck it somewhere completely different,” said Framestore visual effects supervisor Jon Thum. “That was tricky because the helicopter had motion-blurred rotor blades and the original background had distortion from the engine exhaust. The plate had to be re-spaced, as well — and re-spacing a helicopter that has motion-blurred parts is a big job. We could rotoscope the helicopter, but we couldn’t rotoscope the motion-blurred rotor blades or the engine exhaust; so all that stuff had to be regenerated. We tracked in new rotor blades, removed buildings and replaced them with mountains.”

Greg McMurry and a second unit crew captured both aerial and ground-based shots of the convoy traveling through a mountainous area in Lone Pine, California. Production filmed subsequent shots of the convoy being attacked by a mysterious high-tech team at Big Sky Ranch, north of Simi Valley. Digital Domain created matte paintings to bridge the disparate locations, its pipeline allowing Geoffrey Baumann and his digital environment team tremendous flexibility. “We were not locked

into the helicopter plates or anything else that had been shot,” noted Digital Domain visual effects supervisor Bryan Grill. “Projecting plates through our compositing package, Nuke, we were able to rebuild shots and make whatever changes were necessary.”

Digital Domain also created shots of the Typhoon aircraft that flies in, blows up the Special Forces’ craft and vehicles with high-tech concussion weapons, and then lands to expel a team of fighters led by the Baroness, a black-clad villainess who was once Duke’s fiancée, Anna (Sienna Miller). Conceived as a thruster-based helicopter that can hover and then accelerate at very high speeds, much like a Harrier jet, the Typhoon and its weaponry suggested the film’s slightly futuristic setting. “Since this story takes place a few years into the future,” said Boyd Shermis, “we used weapon and craft designs that were on the drawing board at DARPA — the Defense Advanced Research Projects Agency — things that might be in production five or ten years from now. And then we spruced up those designs a bit cosmetically.”

The Typhoon’s concussion cannons emit an energy mass that also suggests a futuristic technology. “It is a very intense volume of air that moves through space and destroys things,” said Shermis. “We decided to give the bad guys a range of these concussion weapons. They have it built into the Typhoon, into the top of their Humvee, in their rifles and pistols. Each of these weapons has a different strength and capacity, but they all share the same fundamental technology. It is a real technology, too, except that, in reality, you would not see anything coming out of the gun. For movie purposes, we had to come up with something that the audience could see, so they could follow what was happening.”

The final look, designed by Digital Domain concept artist Claas Henke, featured rings moving through space, giving the trajectory volume of air a distorted, plasma-like quality. To create a more dynamic effect, the effects team, led by Thomas Reppen, ran multiple fluid simulations — using PSIM, Digital Domain’s proprietary fluid simulation system — representing different aspects of the concussion wave. Compositing supervisor Paul Lambert and his team were responsible for integrating up to 20 3D layers per shot to produce the final effect.

Concussion weapon impacts were a combination of digital and practical effects, the latter orchestrated by special effects supervisor Dan Sudick. On set, Sudick’s team had blown up vehicles and launched



Apache helicopters lift off to escort a convoy transporting the nanomite warheads from the MARS facility in Kyrgyzstan. Live-action for the scene was shot at a military base in Texas. To make the area look more remote, Framestore replaced the entire background with an unpopulated landscape and barren mountains. Framestore rotoscoped the live helicopters to insert them into the new surroundings, but had to digitally regenerate motion-blurred rotor blades, as well as areas of the aircraft distorted by engine exhaust – none of which could be rotoscoped. Framestore also re-timed the plate to create more dynamic action.



A Cobra Typhoon attacks the convoy, blowing up ground vehicles and helicopters with high-tech concussion weapons. Digital Domain created the digital Typhoon, conceived as a high-speed, thruster-based helicopter. To suggest slightly futuristic, yet realistic technology, the visual effects team based the Typhoon and its weaponry on items already on the drawing board at the real-world Defense Advanced Research Projects Agency. Concussion

them into the air. In post, Paul Lambert and his team erased launch rigs and added digital debris to enhance the explosions. The most extensive concussion destruction was for all-CG shots of the Typhoon cannon taking out convoy helicopters. “The impact is like an accordion effect,” said Bryan Grill.

weapon impacts were a combination of digital and practical effects, the latter orchestrated by special effects supervisor Dan Sudick. In post, Digital Domain erased special effects rigs and added digital debris to enhance practical explosions.

“In slow motion, you see it hit and compress the helicopter like a sardine can, and then rip it apart. The helicopter couldn’t just be a shell, either, because once the covering was off you would see all the electronics and mechanisms beneath; so it was a huge undertaking to create all the inner workings of a helicopter, and then rip them apart.” Digital Domain used a rigid dynamics simulation for the helicopter explosion. The action then cuts to a burning, smoking shell on the ground — the only practical helicopter in the sequence.

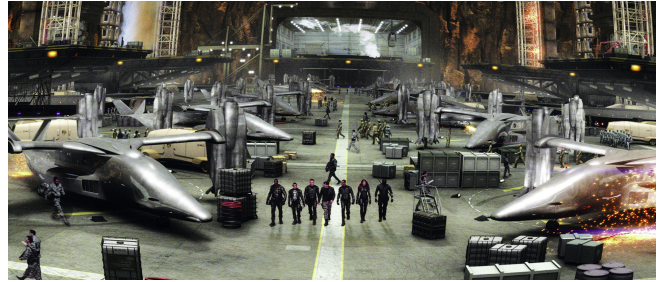
Anna steals the nanomite warheads case and is about to escape with it when the G.I. Joes arrive in the Howler — a futuristic version of an Osprey helicopter currently employed by the Marines. “The Marines’ version is based on propellers,” said Boyd Shermis, “but ours had swivel-tilt jet engines.”

Digital Domain modeled the Howler from art department plans, making some modifications in the process. “Originally,” noted Bryan Grill, “it had a windshield in the front. They changed that to a big hull with no windows — all vision outside the aircraft was done through video or some other kind of electronic monitor system. We also adjusted the wings, which hold the engines, and made the engines able to move independently so that the Howler could do a hovering movement. We based it on known science, and then hoped that the liberties we took were within the realm of believability.”

After the Joes retrieve the warheads, Duke and Ripcord join the elite team, boarding the Howler and returning to a top-secret G.I. Joe base called the Pit, hidden deep inside a sand dune in the Sahara Desert. “When the Howler arrives at the base, we see a flyby of the pyramids — which was an all-virtual environment — and then the approach of the sand dunes and the exterior of the Pit door opening,” observed Boyd Shermis. “That was all done by CIS Hollywood. I had shot some aerial photography at Dumont Dunes near Death Valley. We were able to use that footage as projection material and reference, but we knew we’d never be able to use the aerial footage as plates because the scale wasn’t right. It was a matter of cutting and pasting and tiling and projecting to put that environment together. Greg McMurphy had also filmed some ground-based Vistavision panoramas that we could move around on and tile very effectively.”

Digital Domain delivered its CG Howler model to CIS Hollywood so the team there could create the shot of the sand dune opening up and the aircraft lowering into the Pit, onto a landing platform. “The production plate of the Howler flying into the sand door didn’t really work camera-wise,” explained CIS Hollywood visual effects supervisor Bryan Hirota, “and so we did some photogrammetry to map the terrain and project the plate back onto the geometry. We reworked the camera move so we could fly around the Howler, and then we added the effect of the sand doors opening.”

Greenlit as a digital environment only late in production — after the art department had mostly disbanded — the landing platform environment had to be designed through the visual effects department, which hired illustrator Simon Murton to develop concepts. “CIS took that 2D illustration and created a very detailed, fleshed-out 3D environment,” stated Boyd Shermis. “The only thing we had shot for that was a set about the size of my living room, which isn’t very large.” Diana Miao, at CIS, supervised the development and construction of the landing platform.



New recruits to the G.I. Joe unit, Duke (Channing Tatum) and Ripcord (Marlon Wayans), join their teammates in a Pit hangar in which state-of-the-art military aircraft are parked. CIS Hollywood created massive 3D Pit interiors for sequences throughout the film. In addition to tracking 3D environments into bluescreen plates shot on small partial sets, CIS often replaced set elements, such as painted backdrops representing the Pit’s rock walls, deemed unconvincing in the plate photography. CIS brought additional life to some shots by layering in bluescreen or digital extras.

The action then cuts to a shot of the soldiers disembarking from the aircraft and walking into an elevator — another very small set that consisted only of a small strip of tarmac and the elevator. CIS built a virtual elevator shaft to extend the minimal elevator set, which had consisted of a platform lift capable of moving up and down 30 feet, in front of a bluescreen. The elevator descent briefly reveals every level of the facility, including an aquatic training tank area. “CIS built that whole environment where you see people training,” observed Shermis. “On the water surface you see vehicles buzzing about, firing bazookas and blowing things up. And then, as you travel down vertically, you find underwater submarine training vehicles. There was no water tank footage for this at all — it was all simulated.” CIS used RealFlow Realwave for surface water effects, such as wakes trailing CG boats, and generated additional surface water detail in Maya.

CIS Hollywood also built much of the bottom-most level of the Pit, a cavernous training area revealed as the characters disembark from the elevator. “We had built about half of the actual Pit, at the lowest level, as a set,” said Shermis, “but CIS extended it vertically and in depth, sending the background back another 200 yards.”

In addition to extending minimal sets to suggest a vast environment, CIS had to replace some set pieces. “Shots that weren’t originally going to be visual effects shots became visual effects shots,” noted Hirota. “For example, they had a backing that was painted to look like a rock wall, but in many cases, it was completely unconvincing. We roto’ed everything off of that plate and replaced it with a CG rock wall. We also rendered out generic rock walls to give to Pixel Playground so they could continue the patch job on the Pit.” CIS composited in bluescreen extras or integrated digital characters into shots to populate the Pit and make it look abuzz with activity.

G.I. Joe commander General Hawk (Dennis Quaid) conducts a tour of the Pit, which includes demonstrations of advanced warfare items, such as a camouflage suit that renders a female soldier nearly invisible. The camouflage suit, like all the film's technological creations, had a real-world foundation. "There are Japanese scientists working on these invisibility suits now," noted Hirota, "so Stephen wanted to show one and make it look very realistic. The idea is that the suit has hundreds of little cells that photograph everything around a subject and then project that imagery onto the suit. So the person wearing it isn't really invisible; but they're camouflaged so well it makes it very difficult to see them."



The Moving Picture Company created shots of the underwater MARS base, built on the ocean floor beneath a polar ice cap. Starting with an art department illustration, MPC engaged in a massive 3D build, developing the initial design to suggest a complex that was both ultra-modern and utilitarian. Illumination of the facility came from sunlight breaking through the ice above and lights mounted to the exterior structures. MPC added blooming and hazing light effects, bubble trails and particulate matter to create a realistic underwater environment.

Sommers and Shermis shot the performer — wearing a suit covered with tracking markers — with the 'A' film camera and two HD witness cameras. "We took the girl's performance from set," Hirota noted, "and used that to drive a CG model of the camouflage suit. We looked at what was behind her in the set, and projected that onto this model. To make it more realistic, we introduced lag in areas of the suit that were moving more quickly, as if the cell photography couldn't quite keep up with real time."

The action cuts from the Pit to the underwater facility in which MARS CEO McCullen conducts nefarious affairs. The Moving Picture Company created the underwater MARS base for establishing shots and also for a major end battle in which the base comes under attack by G.I. Joe watercraft. "That was a massive 3D build for MPC," said Boyd Shermis. "They started with an art department illustration of the base; but it evolved design-wise, and MPC's art department made those changes." "Our art department worked on those designs for the first two months we were on the production," said MPC visual effects supervisor Greg Butler. "For the establishing view, we had artwork that gave us a sense of a design theme and a general scale of the facility, including its relationship to the surrounding underwater rock environment." MPC expanded on that artwork, creating designs that were modern but also had an industrial look. "Stephen wanted the base to have a high-tech core, but with a lot of mechanical structures bolted on, breaking up the silhouettes and giving an impression of intensive industrial activity." The MARS base designs also addressed specific story points. "There were shots later in the movie where we were going to see a giant concussion cannon firing, and shots showing three missiles in their silos. There was also a sequence where the Joes infiltrate the base. To hit those story points, we designed specific areas up front, while working on a more general approach to the overall base. Everything was 3D-built. Given the nature of the anticipated camera moves, we knew we weren't going to get away with anything but a full 3D build for the whole thing."

Light sources for the underwater base, located beneath the polar ice cap, included sunlight breaking through thin areas of ice, as well as lights mounted to the exterior base structures. “Sunlight through the ice provided a general key light that would fade off based on the theoretical depth of water,” said Butler. “There were plenty of local sources, too — what Boyd called the ‘rock-and-roll lighting’ that you’d expect on an oil rig, for example. We also made sure there was a glow coming from all the different base windows to give it a lived-in look.”

MPC referenced *The Abyss* to determine a realistic, but practical level of visibility within the simulated underwater environment. “On that film,” said Butler, “there was very little visibility even in shots where you could see the most — and that’s what made it so convincing. For this film, there are shots where there

is up to two kilometers of visibility from the camera to whatever we’re seeing, which is way beyond anything real. Since it was an arctic underwater environment, the water would be as clear as any you’d find on earth; but that would still only get you to about 400 meters of visibility. So we were already extending out the visibility four to five times beyond reality. That meant that there was going to be a significant suspension of disbelief, even if we did everything right.”

To make its underwater environment as realistic as possible, MPC used compositing techniques to make the color fall from the light source above to the subject at the bottom of the ocean, making everything at the furthest point awash in blue. MPC also added blooming and hazing light effects, bubble trails and particulate matter. “There would always be a hanging field of what we called marine snow or detritus — little particles in the water — and those would be affected by things passing by,” said Butler. “We used particles and bobbies to create the bubbles, and a sprite system to generate finer bubbles that created a sense of aerated water — pretty standard effects animation, but huge amounts of it. It was all simulated in Maya, but relied heavily on our in-house effects tools, including custom fields and noise functions.”



Charged with stealing the nanomite warheads is Cobra agent ‘the Baroness’ (Sienna Miller), Duke’s former fiancée. A Framestore establishing shot starts with an aerial view of Paris, and then tilts down to follow the Baroness in a Bentley, on her way to her husband’s estate outside the city. Starting with a helicopter plate that was filmed in the Italian countryside, Framestore created the shot’s background, midground and foreground via multiple matte-painted layers to accommodate the large camera move. Framestore also changed the time setting in the shot from day to twilight, and re-timed the plates to slightly accelerate the camera move.

In one shot inside the base, realized by Framestore, McCullen pushes through a set of doors, revealing the three missiles in their launch silos. “That was a completely CG shot,” said Jon Thum. “From nothing, we had to create a huge silo complete with missiles, gantries, crane and vehicles. We were given the missile models because they were used elsewhere in the film, but everything else had to be designed and built from scratch. We looked at pictures of the space shuttle in a warehouse for the kind of scaffolding and gantries and machinery that might be in a room like that. We were told that the director liked things to be very shiny, and so we made sure there were a lot of reflective surfaces in the room.” The shot also features soldiers, lab technicians and other MARS personnel. “The people were all digital doubles, created in our Massive pipeline to fill out the space. The main thing was filling the room with life, so it wouldn’t look too CG. We added a lot of little details like flashing lights, liquid nitrogen gas coming out of the missiles, and sparks where people were soldering.”

A demonstration inside the MARS facility illustrates a change in emotional state when subjects are injected with a nanomite solution. The altered subjects, called vipers, display no signs of fear or pain, even as one places his arm inside a glass enclosure and is attacked by a cobra. Frantic Films animated a cobra — matching the live snake used on set — created graphics showing microscopic views of the nanomites being injected into the viper’s vein, and digitally extended the set.

Framestore contributed to an aerial shot — seen as the action cuts to France — that starts on a distant view of Paris and then tilts down to follow the Baroness in a Bentley, on her way to her husband’s estate outside the city. “Starting with a helicopter plate that was shot somewhere in the countryside of Italy,” said Jon Thum, “we created the background, midground and foreground with a lot of matte-painted layers. We did an initial matte painting pass of 10 to 15 layers for Paris, fleshing out the city from foreground to background. The Eiffel Tower and the Arc de Triomphe would be on one layer, and other buildings would be on another. Then we filled out the midground and foreground with farmhouses and gardens, because there were just fields in the plate and they wanted it to feel as if it was closer to Paris. We needed all those layers because it was quite a big camera move. After the first round of matte painting, the rest of it was done in compositing, using proper 3D camera inside the composite. We could make changes really quickly that way, just moving the layers around in 3D space.” Framestore also changed the time setting in the shot from day to twilight, and re-timed the plates to slightly accelerate the camera move.

A cut back to the Pit finds Duke and Ripcord in training, learning to handle advanced hardware such as the ‘accelerator suit,’ an electronically enhanced suit of armor that enables wearers to run very



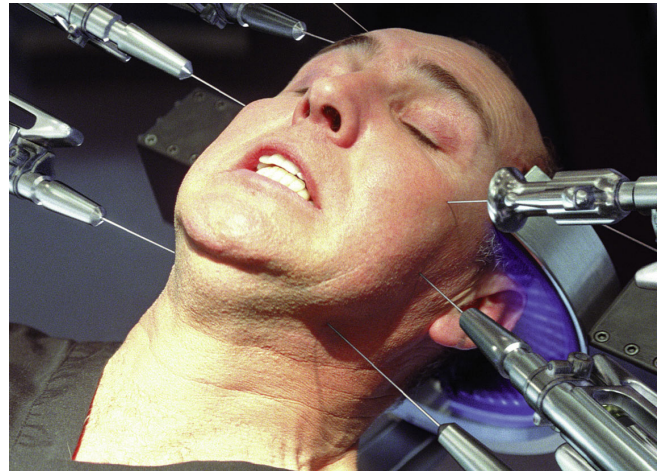
The Baroness and her vipers – nanomite-infected agents – gain entrance to the Pit via mole pods that travel beneath the surface of the desert sand and then drill into the cavern walls. Though CIS Hollywood digitally generated shots of the drilling mole pods, Stan Winston Studio built a practical mole pod from which the performers would emerge on the set. SWS mechanical technicians Seth Hays and David Covarrubias assemble the full-size mole pod prop.

fast. Artists at Stan Winston Studio fleshed out an art department accelerator suit design so that it could be fabricated as a practical suit worn by Channing Tatum and Marlon Wayans. “Stan Winston Studio took what looked great on paper and translated it to something they could actually build and make functional on set,” said Boyd Shermis. “About 90 percent of the time, the suit was CG; but if the characters were standing still or if we saw them in extreme closeup, it was the practical suit.”

Stan Winston Studio started its accelerator suit build by first modeling in XSI, using the 2D art concepts as reference. “From there,” noted SWS effects supervisor Shane Mahan, “there was a lot of traditional model making, done by Dave Merritt’s team. We built the accelerator suits off of a cast of Marlon Wayans, because Channing Tatum hadn’t been cast yet. So we had to retrofit the suit to fit Channing, using Marlon’s body mold.” SWS built a total of six suits: two heroes for Duke and Ripcord, and four stunt versions. “The understructure was a light foam and urethane construction; and then, to make the metal panels as light as possible, we used some lighter-weight urethanes we had developed for the *Iron Man* suits. The suits had to be light enough for the actors and stunt people to run in them; and we got them down to a little less than 30 pounds.”

Training is interrupted when the Pit comes under attack by the Baroness and her vipers, who gain entrance to the facility via mole pods that travel beneath the surface of the desert sand and then drill into the cavern walls. The scene is established in a nighttime desert shot featuring a Bedouin and his camels reacting to the sand being displaced around them as the mole pods burrow through. “We shot some camels and the performer on a ridiculously small bluescreen stage,” stated Boyd Shermis. “CIS took that element and opened it up, using some of our Dumont Dunes ground-based photography to establish the desert environment at night.”

A postproduction decision to change the camera move that had been shot on the bluescreen stage required CIS to rotoscope the animals and performer off the plate and then reposition them within a completely virtual environment. “The surface of the sand was part of our virtual environment,” explained Bryan Hirota. “At the leading edge of the sand, we displaced the textured geometry to get the look of movement beneath it. And then we used volumetric and particle effects for the more turbulent part of the sand displacement. We found that we couldn’t just do it one way or the other — it couldn’t be completely particles because it ended up not scaling right. And we couldn’t do it completely volumetric because it felt too cloudy and smoky. We had to find a balance.” As the vehicle burrowed through the landscape, the sand left behind would settle, leaving a depression. “That went back to our sand geometry. We’d depress that and rework the texture to suggest that it had been disturbed by the underground craft. All of the CG elements were fed to our senior Inferno artist, Greg Oehler.”



At the MARS base, Cobra operative Zartan (Arnold Vosloo) undergoes a facial reconstruction procedure that will drastically change his appearance. Strapped to a table, Zartan’s head is surrounded with needles that inject nanomites into his skull, making his features warp and shift. CafeFX created a Zartan digital double for the scene, using high-resolution facial scans provided by Aguru Images. CafeFX executed a matchmove of the actor in the plate, who writhed as if in agony, and that matchmove drove the animation of the digital double.

CIS extended the interior of the Pit environment for a bluescreen shot of a guard reacting to the drill bits breaking through the cavern walls. “Everything behind that bluescreen guard and everything after the point of impact is virtual,” noted Boyd Shermis. “There’s a big sweeping camera move that travels down as the mole pods individually break through the wall. And then you see the Baroness and a couple of her men step out of their pods and walk out into the Pit area.”

The Baroness and her men engage the G.I. Joes in battle. CIS Hollywood — working with supervisor Randy Goux and his team at CIS Vancouver — created concussion weapon effects for the fight scene. “Boyd gave us some Digital Domain concussion shots that Stephen liked,” said Bryan Hirota, “and we just copied those. We used particle systems in Houdini and Maya to create the effect, rendered out some passes, and then used those passes inside Shake so we could do refraction and other effects as a 2D process. We also added debris to those fight shots because they’d done very little physical destruction on set — certainly not enough to make Stephen happy.”

In the course of the battle, G.I. Joe Heavy Duty (Adewale Akinnuoye-Agbaje) blows up the mole pods, setting vipers on fire. CIS used a Studio Max plug-in called FumeFX to create the synthetic fire and smoke, and the simulation was applied over a CG viper model. “We used our post motion capture system, again, to drive animation of the CG viper,” said Hirota, “and then comped that on top of the real vipers in the plate. There were a lot of CG characters in this sequence, used in shots of the vipers getting impaled or falling down shafts.” CG characters were also required for shots of Cobra martial artist Storm Shadow (Byung-hun Lee) picking up the Baroness and flying out of the Pit — with warhead case in hand — via jet pack. “At that point they are both CG characters. We started with some scans, but they didn’t have the amount of detail we needed; and so we used a lot of reference photographs to build the models.”

Back at the MARS underwater facility, Cobra operative Zartan (Arnold Vosloo) undergoes a facial reconstruction procedure to change his appearance to that of the President of the United States. Strapped down to a table, Zartan’s head is surrounded with needles that inject nanomites into his skull, making his features warp and shift. CafeFX created a Zartan digital double for the scene, using facial scans provided by Aguru Images. “Aguru did incredibly high-resolution facial scanning for us,” said Boyd Shermis, “something on the order of 5 million polygons. I wanted the highest resolution facial quality I could get because I knew that we’d be very close on some of these digital characters. We did use XYZ RGB out of Canada for the body scans, but the facial scans were all done by Aguru.”

Aguru Images used its commercialized version of Paul Debevec’s light dome technology to achieve the high-resolution scans. “The reason I opted to go with that technology,” said Shermis, “is that, beyond just facial resolution, the data it delivers



During a sequence set in Paris, the Baroness uses a concussion weapon to shatter the roof of a glass building, from where she and her team plan to target the Eiffel Tower for nanomite destruction. Production photographed digital stills of Paris and Prague rooftops to provide the view from atop the glass building, an actual structure shot in Prague. Digital Domain re-created the building in CG to accommodate new camera moves and shot compositions, and as a means of removing lights, rigs and crew members reflected in the glass. Digital Domain also rebuilt office interiors seen through the transparent roof and walls, using photographs.

provides both subsurface scattering and bi-directional radius diffusion function. The dome that you scan people in has lights all over it, so it will photograph light samples of the face from hundreds of different angles and directions. And then it pieces it all together so as you move the camera around, relative to where the light is in your scene, it will always know how the face reacts to light at any angle. So in addition to getting the way light penetrates and diffuses underneath the surface, you get a calculation of the way light reflects off the surface. You don't get that from any other scanning technique. It makes the face very lifelike in terms of the way the light reflects and scatters on the skin."

The team at CafeFX — working under visual effects supervisor David Ebner and CG supervisor Seth Lippman — executed a CG matchmove of the actor in the plate, who writhed as if in agony, and that matchmove drove the animation of the digital Zartan. "We made a system where the matchmove point animation was independent of our model shapes," Ebner explained. "So once we applied the matchmove we could still shift the models around. We modeled about five different poses, shaping cheekbones and other facial structures, referencing photographs of boxers being punched. Then we animated the facial muscles and bones to shift in 3D. In the animation program, we were able to put a control point over the face; and by moving the control point, it shifted it, as if you were punching the face with that controller. We set it up so that it would look like a punch and then ripple and relax back to the matchmove. All of that was going on while the actor was still performing; and so, in a way we were able to animate it in nearly real time and just put it on loop play to see how the effect was going. It really sped up the process."



Duke and Ripcord, in electronically enhanced accelerator suits, race through the streets of Paris in pursuit of the Baroness' van. Introduced in an earlier training sequence, the accelerator suits were fabricated by Stan Winston Studio for live-action shots with the actors. Shots of the characters in accelerated motion were realized by Digital Domain, which modeled the armored suits using scans and photographs of the practical suits. Though identical in appearance, each suit was custom-rigged for animation to capture the distinctive gaits and running styles of Channing Tatum and Marlon Wayans.

Anna has the warheads weaponized at a particle accelerator lab in Paris, and then races with her team toward the Eiffel Tower — the intended target of the warhead. Duke and Ripcord, wearing accelerator suits, chase the Baroness and her vipers as they speed through the city streets in a van.

“Halon helped me previz this big chase sequence,” said Boyd Shermis, “and they did a fantastic job. I had a great working relationship with a guy there named Clint Reagan. I spent about six months working with him, fine-tuning that sequence. Once we got it just the way we wanted, we shot good portions of it in Prague before we ever went to Paris. We shot a lot of the flipping cars and other practical components of the accelerator chase there.”



During the street chase, Duke and Ripcord suffer a concussion weapon blast. Final CG accelerator suit characters did not match the Stan Winston Studio versions exactly, as the look of the suit continued to evolve in postproduction. Digital Domain cleaned up production plates shot on the streets of Prague and Paris for the chase sequence, removing practical effects rigs, camera cars and other equipment. Digital Domain also extended streets, using lidar data and photographs from the locations, and added flipping and crashing CG vehicles to augment practical effects work.

After the Prague shoot, the production team went to Paris to film additional plate photography for the chase sequence. “We had moving camera cars shooting Vistavision plates in Paris,” said Shermis. “We also shot aerial reference plates — but you can’t fly a helicopter in Paris, certainly not around the Eiffel Tower, which was very disconcerting to learn after I had designed the sequence. I suddenly realized I couldn’t shoot half the plates I wanted. What they did allow us to do, though, was go up to the top of the Eiffel Tower to aim both digital and Vistavision cameras down, so we were able to get all of the landscape surrounding the tower. There was quite a bit of guerilla second unit work through the streets of Paris, too. We shot a lot of plates in and around the Arc de Triomphe, as well as stills, so that we could virtualize it.”

Digital Domain under the direction of compositing supervisor Michael Maloney, did a lot of cleanup and other work on the Prague and Paris plates. “We were either removing things in the scene that weren’t supposed to be there,” noted Bryan Grill, “or adding things to make Prague look like Paris. We cleaned up a lot of practical effects rigs, camera cars, ramps — you name it. We did a lot of extensions on the streets, too, which we had photographed very thoroughly on location. They had lidar information from the streets, as well; so not only could we extend streets, we could clean up whatever we needed to by completely reconstructing any part of the street.” Digital Domain also added CG vehicles crashing and flipping, augmenting the physical effects work done on location.

Digital Domain created CG versions of the accelerator suits that dominate the sequence, as well, using scans and photos of the practical suits as modeling guides. The look of the suit evolved somewhat once it was in the digital realm. “They decided they wanted it to be more reflective than the practical version,” said Grill, “and because we were doing it in 3D, we were able to play with all of those options.” Although the suits were virtually identical, the running gaits and body languages of Marlon Wayans and Channing Tatum varied significantly enough that the suit models had to be rigged differently. “We did motion capture sessions with House of Moves early on to get the actors’ cadences and gaits so you’d recognize them as they were running in the suits. Animation supervisor Bernd Angerer and his team kept those same characteristics even when motion capture wasn’t

used. With those subtle nuances, you could easily tell who the actor was in the suit just from the way he moved.”

Storm Shadow, armed with the nanomite warheads, climbs to the roof of a large glass office building to target the Eiffel Tower. Production shot digital stills of Paris and Prague rooftops to provide the view from atop the structure. Though the building itself had been shot in Prague, Digital Domain was called upon to re-create it in CG. “A CG glass building was not an easy thing to do,” Boyd Shermis said. “You can do glass in 3D, of course — but to create an entire building made of glass presents a lot of problems, because it’s just a bunch of translucent mirrors. You can see through them, you can see what is reflected off of them. It was a massive feat for them to do that.”

“We rebuilt the interior with photographs in Nuke,” Bryan Grill elaborated, “which we added to plates or used alone. There were a lot of times where they’d shoot a plate to simulate following one of our animated characters; but, then, when we showed them what we could do with the animated character, they would ask us to augment a camera, adding part of the interior to the top and bottom to better preserve the action.” Even shots that were fine in terms of composition and movement required rebuilding so that Digital Domain could remove lights, rigs and crew members reflected in the glass. “When we were shooting, it was, ‘Oh, great, we got this plate and we won’t have to build this.’ But then we’d get it back home and start seeing the camera crane and 50 people reflected in the glass, so we would have to rebuild most of it anyway.”

With the impact of the nanomite warhead, a leg of the Eiffel Tower begins to disintegrate, causing the landmark structure to collapse and crash onto a bridge and then into the Seine River. “Making the Eiffel Tower crash and fall required a lot of rebuilding of the surrounding area and the tower itself,” said Grill. “Except for a plate we used for the first shot of the missile hitting it, the Eiffel Tower was a full CG model. We were lucky enough to have a lot of pictures and video of the tower, as well as books we could draw from. You see every detail from every view, down to the tables and chairs on the different levels and all the light bulbs and sockets lining the exterior. In fact, the Eiffel Tower model was so complex and heavy, we were never able to load the entire build into a single file. There was also an incredible amount of texture work.” Artful lighting by Hanzhi Tang and his team was instrumental in ensuring that the CG tower matched the real structure.

Digital Domain CG supervisors Nikos Kalaitzidis and Swen Gillberg, along with digital effects supervisor Darren Hendler, opted to use a cloth simulation to



Cobra martial artist Storm Shadow (Byung-hun Lee) takes aim at the Eiffel Tower from within the glass building. With the impact of the nanomite warhead, support structures disintegrate, causing the iconic landmark to collapse. To augment limited plate photography of the area — where low-altitude aerial filming was prohibited — Digital Domain rebuilt the tower and environs in 3D, using photographs and video as reference. The final CG tower was exceptionally detailed, down to every light bulb and socket lining the exterior, and heavily textured, based on closeup photographs of Eiffel Tower structures. Digital Domain used a cloth simulation to achieve the look of metal fatigue as nanomites ate away at the tower’s base, and animated the resulting collapse in Maya. In a wide shot of the landmark crashing into a bridge and then the Seine River, Digital Domain removed both the tower and the bridge from the original photographic plate, replaced them with CG versions, added water to create an appropriately scaled splash, and then nestled all of the 3D

achieve the elastic deformation needed to simulate the metal fatigue of the Eiffel Tower after nanomites eat away its support structures. Effects lead Phillip Prahm developed a system in which structures dynamically switched from static to rigid simulation objects while their shape was continually eroding. “This enabled eroding pieces to recognize where they were no longer being supported by surrounding material,” said Grill, “and then begin to realistically fall and collide with other items. The tower was also run through a secondary simulation step in which each of the thousands of trusses and their sub-trusses would bend, shear and snap based on the motion of the tower.” The base Eiffel Tower motion was animated in Maya or simulated in Houdini, and those results were then automatically run through all the simulation steps, including nanomite erosion, metal fatigue simulation and secondary truss simulation.

The Digital Domain crew sought the guidance of an engineering firm in animating the tower’s actual collapse and fall onto the bridge. “None of us has ever seen the Eiffel Tower collapse,” remarked Grill, “so we had no idea what this should look like. So we called these engineers, and asked: ‘What would happen if the Eiffel Tower started to fail?’ If the front leg was eaten away, how would the structure fall?” It was very important that it look plausible. For the most part, we followed the engineering rules; but in a couple of shots, we added Hollywood moments, such as when the tower snaps right in front of the camera — the en-gineers said it would actually snap a little lower.”

In the wide shot of the tower smashing into the bridge and river, Digital Domain removed both the tower and the bridge from the original photographic plate, replaced them with the CG versions, added water to create an appropriately scaled splash, and then nestled all of the 3D imagery into a plate shot from a tall Paris bridge, using a camera attached to a 100-foot-tall construction crane. “The only way to get that angle was to be about 120 feet in the air,” said Boyd Shermis. “Since we couldn’t fly low in that area, we had to put this construction crane up on a bridge to get that height.”

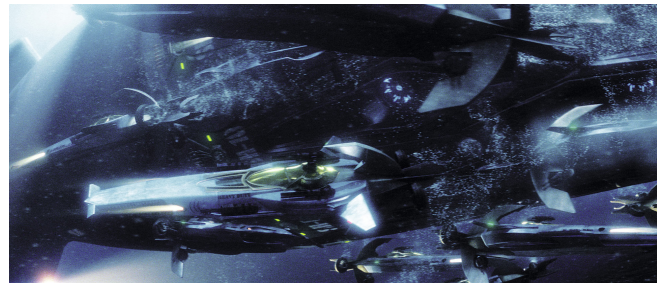
Back at street level, Duke and Ripcord, in their accelerator suits, finally stop the Baroness’ speeding van and capture one of her vipers — but the character self-destructs, disintegrating into a mound of dust before they can extract information from him. CafeFX created the viper disintegration effect for this and other scenes. “The viper in the Paris chase scene is completely eaten away from the inside out,” said David Ebner, “which makes his head collapse. That effect took place over about five shots. We started by doing 2D artwork to show the progression of it, and then we fleshed it out from there. In the final shots, it looks as if the nanomites are eating through the head, with bone structure and muscles collapsing and making the face sink in. There is also a bruising, black effect when it is being eaten away, and blood spills out. Finally, it disintegrates down to dust. They didn’t

imagery into a plate shot from a construction crane atop a tall Paris bridge.
Cobra martial artist Storm Shadow (Byung-hun Lee) takes aim at the Eiffel Tower from within the glass building. With the impact of the nanomite warhead, support structures disintegrate, causing the iconic landmark to collapse. To augment limited plate photography of the area — where low-altitude aerial filming was prohibited — Digital Domain rebuilt the tower and environs in 3D, using photographs and video as reference. The final CG tower was exceptionally detailed, down to every light bulb and socket lining the exterior, and heavily textured, based on closeup photographs of Eiffel Tower structures. Digital Domain used a cloth simulation to achieve the look of metal fatigue as nanomites ate away at the tower’s base, and animated the resulting collapse in Maya. In a wide shot of the landmark crashing into a bridge and then the Seine River, Digital Domain removed both the tower and the bridge from the original photographic plate, replaced them with CG versions, added water to create an appropriately scaled splash, and then nestled all of the 3D imagery into a plate shot from a construction crane atop a tall Paris bridge.

want it to be too gruesome, to avoid rating problems, but the final effect was still very effective. We did a lot of cool programming for the nanomite destruction shots, and that plus a new three-dimensional interface called ICE, which is part of XSI, gave us nearly real-time control of the effects.”

Having learned of McCullen’s part in the Eiffel Tower destruction, the Joes travel by submarine to his secret facility beneath the polar ice cap. The Moving Picture Company created all-synthetic views of the facility from the sub, and also animated a 3D polar bear that reacts when the vessel breaches onto the ice, deploying Joes on snowmobiles to explore an ice cave that will allow them to gain entrance into the MARS lab. Production had shot live-action on a very small ice set outside a stage at Downey Studios. “It was a short set of carved foam,” said Boyd Shermis, “with salt crystals for snow, surrounded by greenscreen; and so every shot in that sequence, both interior and exterior, had to be extended virtually. To give us backgrounds and environments to build from, we had sent a unit out to Norway to photograph some aerials and some land-based HDRI panoramas of ice shelves and glaciers. We used pieces of that to construct our own version of the ice cap.”

CIS Hollywood created the virtual ice cap environments, including interiors and exteriors of an ice cave, designed by artist Robert Stromberg, which houses Typhoons and the high-tech ‘Night Raven’ aircraft. “For the exterior of the ice cave,” said Bryan Hirota, “they’d built maybe 20 feet of ice wall, with some fake snow on the ground. But any of the blowing snow, the sky, the distant mountains and the large icy environment was our virtual environment. The shot where you see the submarine break through the ice was a combination of Houdini and Maya rigid body dynamics to handle the large-scale chunks of ice breaking up; and we used RealFlow to generate the fluid dynamics simulation of the water coming around the sub and dripping off of it as it came out. We worked out the timing and camera move on that, and then shared the shot with MPC, who animated the polar bear.”



The G.I. Joes travel by submarine to the secret underwater MARS base and deploy SHARC submarine craft, initiating a Star Wars-style underwater battle. The Moving Picture Company contributed to the design of the SHARCs, as well as the Mantis Cobra fighters that join the fight, adhering generally to the look of Hasbro’s classic toys. MPC then modeled and animated CG SHARCs and Cobra fighters – with pilots – as well as McCullen’s Trident submarine, seen later in the sequence.

Shermis had asked MPC to provide the animated polar bear because he recalled that the company had generated one, years before, when bidding on another project. “He asked if we still had that polar bear,” said Greg Butler, “because he needed one. We still had it, and we just did some quick upgrades on it using fur technology that we’d developed for Narnia last year. We went back and forth with CIS to establish timings, then gave them a final polar bear render to comp into their shots.”

Beneath the ice cap, General Hawk deploys SHARC submarine craft to attack the MARS base, initiating a huge underwater battle realized by MPC. “Stephen Sommers wanted a classic *Star Wars* style battle, only underwater,” Butler said. “We did design work on the ships you see in that battle — the SHARCs, the Mantis Cobra fighters, and McCullen’s Trident sub. The SHARC and the Mantis were

based on toys that Hasbro made in the eighties, and these ships had to bear some resemblance to them. There was almost no design on the 'Joe sub,' though, the big command vehicle that launches the SHARCs; and so we did that one from scratch."

MPC built generic versions of the SHARCs and Cobra fighters, with pilots, and then built custom versions as needed. "We did a souped-up SHARC for Heavy Duty," said Butler, "because they wanted him to have bigger versions of everything. We put four big chain guns on it, and other bits and pieces just to make his SHARC stand out. We customized some of the paint jobs, too. I looked at the toy designs to see if there was anything we could pull off of them. So, in one instance, the SHARC has a little shark icon on the hood, which I found on some of the old toys."

Among the challenges of the battle sequence was developing underwater explosions in CG. "I talked to some practical effects people to see if this was something we could even try to shoot," said Butler. "It has been done, but it can be very dangerous. So we did it all CG. We took a look at the few good examples of underwater explosions in movies like *Crimson Tide* and *The Hunt for Red October*. The explosions in this sequence are the result of conventional torpedoes being fired by the SHARCs and Mantis. The concussion cannon was a specific, high-energy blast effect; but the Joes shut down the concussion cannon before it does too much damage. Whenever you see explosions going off, it is generally because a torpedo has either exploded near a ship, or a ship has been taken out by one." MPC used Scanline's Flowline simulation package to create the look of explosions in the near weightless environment, with fire and smoke trailing in the water. "Flowline had the right tool set for this effect, and we got really good at these underwater explosions right from the beginning. That was a good thing, too, because Stephen Sommers was always saying, 'More explosions!'"



*A Cobra Mantis pursues a SHARC ship as the warfare intensifies. Among the challenges of the sequence was developing underwater explosions in CG. MPC referenced underwater pyrotechnics in movies such as *Crimson Tide* and *The Hunt for Red October*, and then used Scanline's Flowline simulation package to create the look of explosions in the near weightless environment, with smoke and fire trailing in the water.*

In the heat of battle, McCullen launches the nanomite warhead missiles, targeting London, Moscow and Washington D.C. CIS Hollywood created virtual missile launches, compositing that imagery with greenscreen foreground characters. Ripcord then boards the Night Raven and takes off after the missiles. Production had filmed Marlon Wayans in a Night Raven cockpit, and CIS surrounded that with virtual aircraft and hangar extensions. Frantic Films, which created the Night Raven aerial sequence that followed, built the aircraft model and turned it over to CIS for their hangar shots.

At Frantic Films, look development on the Night Raven began with production concept art and a model mockup illustrating general scale. Frantic Films digital matte lead Ken Nakada then painted more detailed concepts from which the crew modeled the final Night Raven. "We did some pre-modeling first to get our base shape," said Chris Bond, "and then there was quite a bit of refinement to that. We had to be careful how we changed it, though, because there was an approved toy concept already, and we couldn't stray too far from that."

The final Night Raven model was extremely complex, with some 10,000 moving parts. “There were small components all over it,” said Chris Harvey, “moving and adjusting to make it look real. If it rolled or banked hard, flaps and engine pieces would adjust accordingly. Also, if it hit a certain angle at a certain speed there’d be contrails coming off the wing tips. Things like that were all built into the rig. But even though there was a procedural system built in, that could be overdriven and artistically controlled by the animators.”

To capture Ripcord piloting the Night Raven, production filmed Marlon Wayans in a cockpit mockup, mounted to a gimbal. “We shot that in Prague on a bluescreen,” said Boyd Shermis, “with camera cranes flying around him. Then Frantic Films tracked that and dropped it into the 3D version of the flying craft. Everything in those shots — the aircraft, sky and clouds — was virtual. Frantic had done previz on the sequence early, and they’d done a very nice job on it; and so I asked them to do the sequence itself. I turned it over to them very early because I knew this had to be the coolest, best aerial dogfight people had ever seen.”

Toward that end, Frantic Films engaged a specialist in cloud simulations to generate the virtual skies. “Most aerial work in recent films has been executed with real cameras,” commented Chris Bond, “using real plates for backgrounds. But in this sequence, the Night Raven was supposed to be traveling at outrageous speeds — Mach 11, or something like that — and you can’t speed up aerial photography or shoot enough film to get that sense of speed. So we had to create entirely synthetic clouds and sky environments. Looking around at the technology that was out there, we didn’t really see an approach that didn’t have a puffy, cotton-ball cloud look to it. So we developed our own technology, combining a number of tools, including our Krakatoa particle rendering system, to create smoke and cloud elements. Ken Nakada supervised the building of the virtual skies, using these cloud elements and matte painting.”

“To help convey a sense of speed,” added Chris Harvey, “especially in all-sky shots where you don’t see landscapes passing by, we added a lot of thin wispy clouds or particulate in the air or vapor off the plane wing — all manner of things to keep that sense of speed going. At the same time, we were



Exploring an ice cave on the polar ice cap above the MARS base, the Joes discover a highly advanced aircraft developed by MARS Industries, called the Night Raven, which Ripcord pilots to chase and shoot down nanomite warhead missiles targeting London, Moscow and Washington D.C. Working from concept art by Robert Stromberg, CIS Hollywood created a synthetic ice cave hangar and background Typhoon aircraft. CIS artists also composited the Night Raven – a CG model realized by Frantic Films – into the foreground of its virtual environment.



Flying over Washington D.C.. in the Night Raven, Ripcord shoots down the missile and carries the nanomite swarm high above the city. Frantic Films integrated its 3D Night Raven model into virtual Washington D.C. imagery and skies to simulate Mach 11 flight speed. The nanomite cloud consisted of billions of particles rendered in Frantic’s Krakatoa software. Frantic wrote custom code to suggest intelligent behavior in the swarm as it moved across the surface of the craft, eating away the metal to reveal its internal mechanisms, all of which had to be fully modeled in 3D.

trying to create a story arc through the sequence. If the aircraft is always moving at Mach 11, then it never is, because it is just the same thing all the time. We had to build the story arc so that you would feel the intensity grow as the sequence progressed.”

Frantic also virtualized Washington D.C. for shots of the Night Raven following the missile as it travels along the Potomac River toward the White House. Reference imagery for the Washington D.C. build consisted of helicopter footage shot by Boyd Shermis and 16,000 digital stills shot by a Frantic Films unit over the course of four days. “We couldn’t get access to the White House grounds to shoot, of course,” said Chris Bond, “but we got as close as possible, both on the ground and on nearby rooftops. We shot all this reference material and mapped out the whole path of the jet, which was quite long. We had to create very large environments because, even in a single second, the jet covered a lot of distance.”

“Frantic really came through on this sequence,” Boyd Shermis commented. “The photorealism of that aerial environment and the way we move through it is better and more exciting than anything I’ve ever seen. And we got that because we were able to completely virtualize it, without having to rely on aerial photography shot from a helicopter.”

As the Joes infiltrate the MARS base, McCullen and Cobra Commander (Joseph Gordon-Levitt) escape in the Trident sub. CafeFX created the underwater views from inside the submarine. “We had developed an entire underwater environment when we were bidding on the show,” recalled David Ebner, “so we had that 3D environment all ready to go. There were rocks and plant life clinging to the rocks, and detritus in the water. We also did some matte paintings for the buildings in the background.”

MPC delivered shots of the MARS base being destroyed when McCullen and Cobra Commander, from the Trident, blow up the ice pack above it. “They detonate these explosions in the ice pack,” stated Greg Butler, “which brings huge chunks of ice down onto the base, demolishing it. Early on, there were a lot of discussions about the fact that ice doesn’t sink. Even heavy ice floats — so how would these chunks of ice fall through the water? To solve that, we sold the idea earlier that there were metallic tunnels and structures woven into the ice, which would make it sink and slam into the base. We hand-modeled a couple of hero ice pieces, and then built a library of more generic ones. We used procedural animation based on particles to create a sense of them falling as a group and obeying the rules of underwater gravity. But then, effects artists would take over and move things around as needed, giving a couple of the big chunks a little bit of rotation as they fell through the water. It was never a complete simulation or complete keyframing, but rather a combination of the two.”

The last shot in the sequence reveals the remains of the base and the giant concussion cannon disappearing into an ocean floor chasm, along with the McCullen family mask — a reminder of the fate of the McCullen ancestor. Family history is repeated when a weapons exchange with Duke sears a nanomite-based helmet onto McCullen’s head, transforming him into the villainous Destro. CafeFX



MPC delivered shots of the MARS base being destroyed with the explosion of the ice pack above it. Artists hand-

created the transformation effect. “His face first begins to burn,” explained David Ebner, “which is a practical makeup application. Then, digitally, we heal the skin a bit as you see all these little nanomites crawling under his skin. And then the skin begins to blister, with black blisters taking over his whole head. Finally, the blisters turn silver, forming the Destro mask. For the look of the mask itself, we had to collaborate with Hasbro, as well as Stephen Sommers and Boyd, because there is a toy version of the character. We went back and forth with different head designs until we came up with the approved version.”

modeled hero ice pieces for the scene, and then built a library of more generic ones. MPC employed procedural animation based on particles to make the ice chunks fall as a group according to the rules of underwater gravity. Effects artists would then manipulate individual pieces to enhance drama and aesthetics. To justify the ice falling through the water rather than floating, MPC created the look of metallic structures woven throughout it.

The final Destro head was slightly narrower than the helmeted character in the plates, requiring CafeFX to erase parts of the real head and restore bits of background. “The location of the mouth and eyes was somewhat different than what was in the final mask, too,” said Ebner, “which meant we had to grab those areas from the footage and relocate them. So there was a lot of complicated 3D technical work that went into it, from matchmoving, to reprojecting the matchmove onto the mask model, to altering the mask model into the final approved design.”

The film concludes with the Joes having beaten — at least temporarily — the Cobra organization, and with Anna held aboard an aircraft carrier. Framestore executed an extended pullout that starts inside the corridor of the aircraft carrier, pulls out through a window and continues to pull back, helicopter style, to reveal the ship at sea. Other than a plate featuring a small interior corridor set, everything in the shot — the ocean, the aircraft carrier and the beautiful sunset sky — was CG.

Framestore modeled the aircraft carrier based on real ones in the U.S. Navy fleet, but adapted it to more closely resemble the toy version in Hasbro’s G.I. Joe product line. “It didn’t have to match the toy exactly,” said Jon Thum, “but we had to make slight changes to the layout of the deck and runways, and we had to add a logo in a convenient position for the camera to see it in the shot. Other than those adaptations, it was based on a real aircraft carrier. We had to build in a lot of detail and texturing for the beginning of the shot, which starts very close on the ship. And then, for the end of the shot, the trick was just making it look real. An aircraft carrier at sea is something that everyone instantly recognizes; and so we had to work really hard to make sure this all-CG image looked absolutely real.”

Working in Houdini, Framestore generated the ocean surface utilizing a standard mathematical model, applied as a displacement map. “We’ve done CG oceans before,” Thum observed, “for projects like *Superman Returns*; and so we had the setup to make it work. The mathematical model works quite well, generally, but you tend to see repetition in it because it’s a tiled surface. So a lot of the work is just in breaking up the repetitious pattern. We then added whitecaps and sea foam to make it look like a



Framestore executed a nearly all-CG shot that starts inside the corridor of an aircraft carrier, where the Baroness is being held, and then pulls back to reveal the ship at sea. Framestore modeled the aircraft carrier based on those in the U.S. Navy fleet, adapted to resemble

rougher sea. We also added particle whitewater around the edge of the hull and a huge wake in the back. All of those we added in separate effects passes.”

Hasbro's toy version. Working in Houdini, Framestore generated the ocean surface employing a standard mathematical model, applied as a displacement map, then added whitecaps and sea foam to make it look like a rougher sea, as well as particle whitewater around the hull and a large trailing wake.

In a stirring final shot, the victorious G.I. Joes exit the Pit in the Howler for yet another mission — a

conclusion that perfectly sets the stage for a movie franchise that may be selling the popcorn and putting Joe enthusiasts into theater seats for many summers to come. If Boyd Shermis is called in again to oversee the visual effects, he will rely on the same multiple-vendor approach that enabled him to deliver more than 1,600 effects shots relatively quickly for G.I. Joe: The Rise of Cobra. “It has always been my philosophy to utilize talent all around town,” observed Shermis. “I find people who are particularly good at doing certain things, and can do them very efficiently. And because they can do them efficiently, they can do them cost-effectively.”

Efficiency and cost-effectiveness were essential to a director whose filmmaking philosophy appears to be ‘more is more.’ “Stephen Sommers is a guy who likes things big,” said Bryan Hirota. “I saw a quote attributed to a supervisor at ILM who had worked on one or both of the Mummy movies, and he said, ‘There’s big, there’s really big, and then there’s Stephen Sommers big.’ I found that to be true on this show. G.I. Joe was definitely ‘Stephen Sommers big.’”

G.I. Joe: The Rise of Cobra photographs copyright © 2009 by Paramount Pictures. All rights reserved. Special thanks to Ngoc Nguyen, Crystal Shin, Greg McMurphy, Lyn-Del Pedersen, Ellen Pasternack, Rita Cahill, Tim Enstice, Chris Slaughter, Jim Charmatz, and Gemma Samuell.

Earth, Wind and Fire

ARTICLE BY JOE FORDHAM

Toward the end of postproduction on *Harry Potter and the Order of the Phoenix* — the fifth film based on J.K. Rowling’s literary juggernaut — visual effects supervisor Tim Burke and visual effects producer Emma Norton were deep into preparations for *Harry Potter and the Half-Blood Prince*, the sixth in the series. Winding down one film while gearing up for the next at England’s Leavesden Studios had become a well-honed practice for the team; and this time, they were preparing and budgeting magical goings-on as young *Harry Potter* neared graduation at Hogwarts School of Witchcraft and Wizardry.

The screenplay by Steve Kloves streamlined Rowling’s 652-page narrative into 153 minutes, and featured Death Eater demon attacks, flying broomstick Quidditch action and mysterious ‘pensieve’ memory journeys that lead Harry (Daniel Radcliffe) and his mentor, Professor Albus Dumbledore (Michael Gambon), on a quest to retrieve a fragment of the Dark Lord Voldemort’s splintered soul.

Director David Yates, returning for his second Potter film, drew up plans for the production with an eye toward the final novel, *Harry Potter and the Deathly Hallows*. “There was a conscious decision on *Half-Blood Prince* to keep action based around dialogue and drama,” noted Tim Burke. “We’d had wand battles before, and there is going to be a tremendous number of them in *Deathly Hallows*; but David saw this film more as a story of adolescence and young relationships. His approach was to treat it less as a visual effects film, and more as a drama.”

Joining Yates on the production was director of photography Bruno Delbonnel, making his Potter film debut, and series regulars such as production designer Stuart Craig, special effects supervisor John Richardson, makeup effects and creature designer Nick Dudman, and Cinesite model unit supervisor José Granell. Visual effects supervisors Chris Shaw and John Moffatt assisted with second- and third-

image



Harry Potter and the Half-Blood Prince, sixth in the film series chronicling the education of adolescent wizard Harry Potter, opens with vaporous Death Eaters barnstorming real-world ‘muggle’ London. Director David Yates, on his second Potter assignment, re-teamed with franchise veterans including production designer Stuart Craig, visual effects supervisor Tim Burke, special effects supervisor John Richardson, and makeup effects and creature designer Nick Dudman. Double Negative handled the Death Eater attack using digital smoke simulations and photogrammetry tools to rebuild a large section of Central London.



Death Eaters commit a parting act of vandalism, ripping apart the Millennium Footbridge. The production shot plates of the steel and concrete suspension bridge from a crane on the south bank of the Thames, and filmed closeups of terrified pedestrians on a greenscreen set at

unit effects duties, allowing Tim Burke to maintain an overview of vendors in London, California and Australia. Returning vendors included Double Negative, The Moving Picture Company, Industrial Light & Magic and Rising Sun Pictures, joined by Cinesite, Framestore and, new to the franchise, Luma Pictures.

Leavesden Studios. Double Negative photographed reference imagery of the London location, digitally painted out the real bridge, and re-created the span and surrounding environment in CG. Animators keyframed bridge deformations, and effects artists applied dynamic simulations of planks and cables snapping, and debris splashing into the water.

The film opens with vaporous Death Eater apparitions emanating from a supernatural cloud formation above the River Thames and wreaking havoc around London. Yates shot interiors for the Thameside scene at Leavesden in a greenscreen-backed set representing an office in London's City Hall. Double Negative used its volumetric render tool, dnSquirt, to generate window views of clouds forming Voldemort's sinister skull-and-serpent Dark Mark insignia and Death Eater emissions. "Squirt really came into its own on this show," said Double Negative visual effects supervisor Paul Franklin, who shared credit with visual effects supervisor Mattias Lindahl and 2D supervisor Paul Riddle. "It gave us precise control over fluids, allowing us to fill 3D shapes, with vapor dissolving at the edges. The Dark Mark looked like a natural skull-like cloud in constant motion, never completely resolved."

To simulate Death Eaters rocketing down into the city, Double Negative developed swirling spectral forms beyond those they had created for previous Potter films. "The Death Eaters traveled further and faster than they had before," explained Franklin. "It was a big challenge to get our simulations to hold up under speeds of hundreds of miles an hour, because at those speeds the smoke plumes completely broke up. We first simulated smoke emitting from target objects twisting through the air. We then used *Side Effects Houdini* to emit soft-body ribbons and, in the process, tweaked the speed, keeping it fast enough to fit the dynamics of the shot. It took a lot of creative balancing to achieve the effect we needed and make the speed convincing."

In one shot, Death Eaters dive into Trafalgar Square from a height of 10,000 feet. "David wanted it to be a rollercoaster ride through London at fighter pilot speed," remarked Tim Burke. "There was no way we were going to attempt to shoot backgrounds for that live, so we used photogrammetry tools that Double Negative had developed and digitally rebuilt that entire section of Central London."

Paul Riddle oversaw a high-altitude point of view looking down over the city — a vast hand-painted digital environment based on satellite photography and Ordnance Survey maps. Artists generated textures for the River Thames in Double Negative's dnOcean renderer, and populated the city with trees generated in a procedural modeling system developed in Houdini. For lower-level views, sequence lead Phil Johnson gathered textures using a Canon 1DS digital single lens reflex camera mounted to a helicopter flying at approximately 800 feet over Central London. Double Negative shot street-level photographic textures on foot, while walking from Trafalgar Square through Charing Cross Road. "The stills served as a highly detailed survey," noted Franklin. "We used them to reconstruct architecture, and created levels of detail depending on proximity to camera. Lighting conditions were pretty close to the conditions David wanted in the shot, overcast and moody, so the stills were fantastic reference for compositors and 3D artists to get the lighting right."

Double Negative added pedestrians and automobiles using 3D-animated crowd technology developed for *The Dark Knight*, combined with keyframe animation of vehicles. The Death Eater flight culminates at The Leaky Cauldron pub, entry to a hidden wizard realm. “We wanted to link our ‘muggle’ world with the wizard world,” noted Tim Burke. “The idea was that the entrance to The Leaky Cauldron was right on our doorstep, down a little alley off Charing Cross Road.”



Albus Dumbledore (Michael Gambon), headmaster of Hogwarts School of Witchcraft and Wizardry, pays a visit to an old colleague, Professor Horace Slughorn (Jim Broadbent), who has curiously disguised himself as an armchair. For Slughorn's transformation from armchair to man, as Dumbledore wields an unmasking spell, Broadbent sat on a teeterboard with his limbs aligned to those of the armchair, then sprang to his feet, shaking and blithering. Rising Sun Pictures blended digital transforming chair extensions to the actor's body, and covered chair geometry with cloth simulations resembling Slughorn's silk pajamas.

Double Negative built a highly detailed model of Charing Cross and adjoining Great Newport Street, and swapped out a storefront with The Leaky Cauldron façade. Modelers built the pub interior from photo surveys of a Leavesden set used in previous films, which the camera traverses in 20 frames. The camera then exits to a courtyard, and blasts through a brick wall into Diagon Alley, the wizard world's main street. Double Negative shot lidar and photo surveys of the Leavesden Diagon Alley set, modeled the location digitally, added wizard pedestrians and dovetailed the computer generated camera move into a practical wire-flown camera that accelerated toward Ollivander's wand shop.

The Death Eaters cause the shop front windows to explode, staged as a practical effect. "The camera was flying down the road at about six meters per second," said John Richardson. "We had to time multiple detonations as the camera traveled by the shop in about 24 frames, so we were dealing with fractions of a second for the windows blowing out and fireballs traveling through the shop. We rigged everything using a signal from the wire-flown camera, which tripped a multi-way firing box. We worked out timings using flashbulbs, then hooked up our firing box and sequenced that to our pyrotechnics."

Following the raid on Diagon Alley, Death Eaters take flight back toward the Thames and, in an act of gleeful vandalism, rip apart the London Millennium Footbridge. The production shot establishing views from a crane mounted on the south bank of the river, and then reconstructed a portion of the bridge backed by greenscreen at Leavesden. John Richardson's crew built closeup insert pieces for shots of cables snapping and bolts exploding, which served as the basis for fully digital versions that Double Negative created in Maya and the studio's dynamics tool, dnDynamite. Double Negative rebuilt the environment for the collapsing bridge. "We added stormy clouds from stills shot off the roof of Double Negative," recalled Paul Franklin. "Closeups of the undulating bridge featured the Leavesden set with a background created from the location stills. For wide shots of the bridge pitching around, we digitally removed the real bridge and river, and added a CG bridge and river with CG people running back and forth." Double Negative keyframe-animated the bridge for twisting and warping motions and applied secondary animation in dnDynamite to create planks springing off and cables snapping. The final collapse featured a fully synthetic environment with dnSquirt splash simulations.



Albus Dumbledore (Michael Gambon), headmaster of Hogwarts School of Witchcraft and Wizardry, pays a visit to an old colleague, Professor Horace Slughorn (Jim Broadbent), who has curiously disguised himself as an armchair. For Slughorn's transformation from armchair to man, as Dumbledore wields an unmasking spell, Broadbent sat on a teeterboard with his limbs aligned to those of the armchair, then sprang to his feet, shaking and blithering. Rising Sun Pictures blended digital transforming chair extensions to the actor's body, and covered chair geometry with cloth simulations resembling Slughorn's silk pajamas.

Death Eater attacks prompt Dumbledore to seek out Harry Potter in a suburban London train station, where Harry glimpses Dumbledore's withered right hand — evidence of a recent wand duel. For shots featuring the injury, Michael Gambon wore a glove made of greenscreen material affixed with tracking markers. Rising Sun Pictures then produced a series of digital degeneration effects tracked to the glove based on cyberscan geometry and textures derived from photographic studies of the actor's skin. "We created three stages of decay," said RSP visual effects supervisor Gregory Yepes. "It started with a little decay around Dumbledore's ring finger, as if the flesh was dying around the ring and adjacent fingers. By the end of the movie, the decay progressed to cover his hand. It helped that Michael Gambon downplayed the injury, so most of the time when he held a wand, he held it in his other hand. But it was still a challenging matchmove to re-create the CG fingers and make sure they didn't slide about relative to the rest of the hand."

Dumbledore whisks Harry from the train station to the distant village of Budleigh Babberton using an 'apparating' spell — a powerful magical method of instantaneous transportation wielded by senior wizards. David Yates sought to represent the effect with a visceral and disorienting transition. "When Dumbledore takes Harry to the village," noted Tim Burke, "it is the first time Harry apparates, and David wanted audiences to feel what Harry was experiencing. Going from descriptions in the book, I tried to make the effect feel solid and not too ethereal."

Burke discovered intriguing reference imagery in slitscan photography, a pre-digital technique of moving mattes, long exposures and incremental camera motion that produced bizarre photorealistic distortions. "I thought it would be interesting if we could make a three-dimensional object appear to unwind as the camera flew around it," observed Burke. "I chatted with Nicolas Aithadi at MPC about how we could apply that to human forms to not only unwrap them, but also combine them, so bits of Dumbledore and Harry would mix together. We applied that idea to the environment; so, for a split second, all their body parts combined, like Henry Moore sculptures, and then unwrapped elsewhere."

MPC illustrated the effect in abstract conceptual art. "One of our artists, Paul Catlin, produced some amazing artwork," related MPC visual effects supervisor Nicolas Aithadi. "They were stunning images of melted faces and bodies, an eye here, an ear there, fused together and set in jelly. Tim liked them and David liked them; but I thought to myself: 'Damn! How do we do that?'"



Harry (Daniel Radcliffe) and fellow Hogwarts student Luna Lovegood (Evanna Lynch) approach the school's main gate, where Professor Filius Flitwick (Warwick Davis) inspects arriving students' luggage. David Yates filmed the scene on location in Windsor Great Park, Surrey, with Davis wearing prosthetic makeup supplied by Nick Dudman's team. Cinesite model unit supervisor José Granell supplied film elements of the ever-evolving Hogwarts miniature, which were merged into the environment by Cinesite compositors. Cinesite also created an animated bird zapped by a magical force field protecting the castle perimeter.

Aithadi's team dove into shot production in Pixologic ZBrush and created a series of 3D models based on six pieces of conceptual art. Modelers developed blend shapes to bridge transitions between models in Autodesk Maya and worked with animators to establish timings. "We started with models of Harry and Dumbledore," noted Aithadi. "Our lead rigger, Dan Zelcs, created a special rig that could deform the faces and bodies while keeping them 'animatable.' Our animators did preliminary animation to establish timings. The modelers worked on top of that, extracted geometry every five frames, reworking the model in ZBrush, and building high-resolution blend-shapes to create smooth transitions. It was a long process."

To integrate twisting bodies into environments, MPC created 3D models of production plates, projected textures from the plate onto the geometry, and then created blend shapes between corresponding portions of the two locales. "We added deformations to make the platform twist as it re-created itself into the village," said Aithadi. "We then rendered a still texture of the train station deforming, and did the same thing with a still texture of the village. We composited those two elements, chose where to blend from one to the other, and added light effects to make it look like they were traveling."

Dumbledore and Harry find Horace Slughorn (Jim Broadbent), a retired Hogwarts potions master, hiding inside his apparently wrecked home by impersonating an armchair, from which he transforms back to human form. To set the scene, the production filmed a practical armchair with striped fabric similar to Slughorn's pajamas. Yates then shot the transformation by seating Broadbent on a teeterboard, with his limbs spaced to correspond with the geometry of the armchair. "We used the teeterboard to flick Jim up in the air," explained Tim Burke. "He then stood up, shaking, in an 'I'm-turning-from-an-armchair-into-a-human' performance."

Tim Burke's team provided color chart photo reference, high dynamic range imagery, lidar scans and blueprints to Rising Sun Pictures, which generated a duplicate chair that vocalized as Dumbledore prodded it with his wand. "The second he got poked," recalled Gregory Yepes, "Jim Broadbent opened his eyes and said, 'Merlin's beard!' From that point on, we used the actor's head. The rest of the armchair constituting his body ceased to be a practical element and became a CG extension of Slughorn. As his body transformed from chair to pajamas, we blended each section of the chair to a part of Slughorn's body, while matching his performance. We built blend shapes for different parts of the body, and then did cloth simulations on top to resemble the motion of Slughorn's pajamas."



In a memory sequence in which he first meets the young Dark Lord Voldemort, Tom Riddle (Hero Fiennes-Tiffin), Dumbledore demonstrates his ability to magically manipulate fire, causing a wardrobe to burst into flames. The production filmed the scene on a set at Leavesden Studios representing an interior of the Dickensian orphanage where the boy resides. John Richardson's team supplied flame bars to cast firelight on the performers and the set, and then built and rigged a black metal replica of the wardrobe for a pyrotechnic element shoot. Cinesite composited the fire into production plates.

Dumbledore and Slughorn use a spell that repairs wreckage around the room, causing scattered furniture to hop back into place. “Tim asked us to animate the effects to music,” stated Yepes. “He wanted the reverse destruction to have a choreographed rhythm, as opposed to simply running simulations in reverse. Timings were very clear for big props like the piano and chairs. We created CG inserts of other pieces, grouping items. The camera was traveling around the room, focusing on the characters, so some pieces flew around Harry, trying to get back where they belonged.” Animators brought to life more than 200 CG props in the scene, including a large crystal chandelier, which required keyframe and procedural dynamics to choreograph the object’s myriad parts.



Ron Weasley (Rupert Grint) suffers a crisis of confidence as keeper of the Gryffindor Quidditch team. The magical sporting event received an effects makeover to enhance the excitement of the game. John Richardson’s team revamped existing mechanical flying rigs to create more dynamic bluescreen elements of players on broomstick mounts, and MPC previzualized and animated scenes to emulate sports photography, with swooping camera moves and dexterous hand-offs to digital character animation.

Both Harry and Slughorn return to Hogwarts, the former aboard the Hogwarts Express, a CG locomotive generated at MPC, seen traversing the Scottish countryside. Establishing views of Hogwarts incorporated location photography filmed in Scotland and elements of the 1/24-scale Hogwarts miniature, shot at Shepperton Studios under the supervision of José Granell and director of miniature photography Nigel Stone. The production filmed scenes approaching the school in Windsor Great Park, Surrey, and Cinesite 2D supervisor Andy Robinson oversaw compositing of the Hogwarts miniature into the tree-lined walk.

Harry Potter’s year at Hogwarts is plagued by romantic complications, some caused by an infatuating love potion, which Luma Pictures created as particle animated heart-shaped bubbles. In other scenes, a magical flock of lovebirds, animated at Cinesite, twitter around Hermione Granger (Emma Watson) and then dive-bomb Ron Weasley (Rupert Grint), the object of her frustration.

Hermione scolds Harry for flaunting his popularity in a library scene, where floating books glide back and forth between shelves. The production filmed the scene using John Richardson’s practical wire-flown levitation effects and green-gloved performers who reached through bookshelves to pass books back and forth to student performers. Luma removed rigs and greenscreen arms, and added 3D animated books. “When a girl walked by in the background with a huge stack of levitating books,” explained Luma visual effects supervisor Vince Cirelli, “that was one of ours. Also in that sequence, one of the boys has a big book open with a Playwitch magazine hidden inside. The production provided us with footage of a girl in a witch’s hat, scantily clad. We composited her into the magazine, throwing kisses.”

Harry faces more pressing issues when Dumbledore instructs him in private pensieve lessons that delve into the Dark Lord Voldemort's past. The pensieve — introduced in earlier films as a stone font into which memories can be poured — was redesigned as a floating silver dish containing liquid that revealed inky fluid visions. "The pensieve liquid acted like a catalyst," said Tim Burke. "It caused images to form, like ink poured into water, which then became a memory. We shot memory scenes with characters on greenscreen, then built up backgrounds using layers of elements and fluid simulations. Double Negative did a lot of work creating the look."

The first memory scene follows a younger Dumbledore through a London street to an orphanage where he meets Voldemort as a child named Tom Riddle (Hero Fiennes-Tiffin). Stuart Craig adapted an existing set at Leavesden to represent the orphanage façade. Michael Gambon performed the scene walking toward greenscreen. Double Negative keyed Gambon from the plate and digitally replaced the street with three-dimensional volumes. "We made containers out of the buildings and filled them with swirling ink effects in dnSquirt," stated Paul Franklin. "We made the ink bleed outside objects by controlling fluids with force fields. We also used practical ink elements that we shot as tests. We had an ordinary fish tank, about four feet across. We dropped black ink into the water against white, and shot that on low-def video. As we were putting shots together, we realized those elements could be useful as background effects, so we luma-keyed ink swirls from the background, which helped establish timings for our simulations. The compositing team did a tremendous job pulling that scene together. They had hundreds of layers — all the buildings resolving, Dumbledore resolving, the road, the rain and a complex camera move."

Stuart Craig built orphanage interiors at Leavesden for a scene in which Dumbledore demonstrates supernatural powers for Riddle, causing a wardrobe to spontaneously combust. John Richardson supplied flame bars to create interactive lighting on set. The effects team later provided a separate pyrotechnic element to simulate the wardrobe burn. "We built a replica of the wooden wardrobe in black metal," said John Richardson. "We ran flammable liquid down it, and burned propane up it,



The Hogwarts Express transports students home for Christmas. The production returned to familiar locations in Scotland to film most of the scenic textures used in generating rural landscapes around Hogwarts, and used aerial plates shot in Norway for snow-covered terrain. MPC generated a digital model of the locomotive and tracked it into plates with digital railroad tracks and ties, particle simulations of venting steam, and layers of atmospheric effects, including falling snow.



On a country road, student Katie Bell (Georgina Leonidas) levitates, possessed, after touching a cursed necklace. John Richardson's team supplied wire rigs, including a four-winch cable system with a rigid body form molded to Leonidas' body, to float the actress on set. For aerial shots, Leonidas performed against bluescreen in a water tank, which created eerie floating motions in her hair and clothing. Double Negative removed the bubbles, composited the girl with digital set extensions and falling snow, and used hand-painted holdout mattes to grade the shot and create atmospheric depth and fogging.

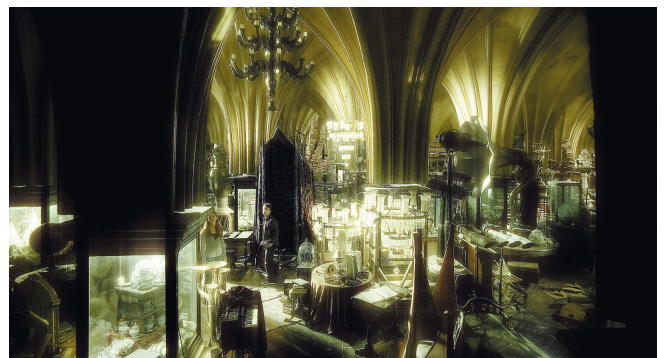
mingling the two together to give quite an interesting looking flame.” Cinesite combined pyrotechnic elements with interactive lighting, and digitally rebuilt portions of the plates.

A later pensieve vision reveals Slughorn’s emotional outburst at an adolescent Tom Riddle (Frank Dillane), tearing apart the liquid fabric of the scene. “It was great to have such strong motivation in the plate to activate the dynamics of the effect,” Paul Franklin commented. “As Slughorn yelled at Riddle, it created a violent break-up of the image. We had smoky material swirl up around Slughorn and warp the background. It was an idea we brought to pensieve scenes quite late in the design process, and we didn’t have any textures for outside the borders of the frame, so we brought in more layers of fluid effects to fill those areas.”

Less disturbing activities at Hogwarts include a return to the flying broomstick wizard tournament of Quidditch. “It is the last time we will see Quidditch in a *Harry Potter* film,” remarked Tim Burke, “so David wanted to send it off with a bang. We had Quidditch trials, and a Quidditch match. The trials were predominantly about Ron, playing on his inadequacies in the keeper role. David wanted to introduce humor into that, a lot of which we shot on the bluescreen stage, relying on Rupert Grint’s performance. David also likened the trials to Saturday morning rugby games in the middle of winter. We used just the raw superstructure of the stadium, with no banners, and everything was very muddy, with kids falling off their brooms and splashing into puddles.”

To facilitate the bluescreen rider shoot, the physical effects team gave mechanical flying rigs an overhaul. “We completely rebuilt our broomstick motion base,” said John Richardson. “We refitted everything with electronic actuators, and no hydraulics. That made the rig more responsive, and more compatible with visual effects programming.” Richardson worked with stunt coordinator Greg Powell to rig mechanical means for supporting and unseating the Quidditch riders. “We had about eight different broomstick setups. Some involved traditional rigs that Ron was harnessed onto. On others, he was sitting on the rig, wired from above, so he could literally stand on the broom. We got more physical interaction on the crashes and landings using a Russian swing to throw stuntmen through the air into rubber padded floors. That was a double-ended swing, like acrobats use in the circus: a pair of stuntmen stood on one end of the swing, and got it swinging fast, and then another stunt performer used the velocity of the swing to throw himself 40 feet through the air.”

As in prior films, the Quidditch arena of wooden bleachers and tall goal hoops around a grassy field was a virtual environment that incorporated scenic textures shot in Glencoe and Glen Nevis, Scotland. The production used a set at Leavesden to represent a portion of the stands for audience closeups, and provided blueprints of the stadium to MPC, which rebuilt the environment from scratch with modifications to enhance game play. “In previous films,” observed Tim Burke, “we felt that the Quidditch environment had been too spread out. We frequently had shots of players flying against sky without any other background to create a sense of



Harry and Ginny Weasley (Bonnie Wright) enter the Room of Requirement, a cavernous storage room accessed through a magically concealed door. The room, previously seen empty in *Harry Potter and the Order of the Phoenix*, was designed to be a menacing environment containing an apparently infinite array of wizard paraphernalia. The production built the room as a partial set stacked with

speed. Working with Stuart Craig, we decided to center the stadium in the middle of a steep bowl. At one end, we had the school. At the other, where there used to be a low valley, we chose an area of Glen Nevis, called Steall Falls, which had a huge 150-foot waterfall. We shot rock and running water textures in Scotland, and placed those behind the stadium. By bringing the environment closer, characters were always flying against the mountainside or the stadium, which created parallax and an exciting sense of speed.”

props, including a sinister black obelisk – a vanishing cabinet. Double Negative digitally extended the architecture, adding arches in the background, and built a library of photographic assets to dress the set with artifacts.

MPC created the stadium superstructure as a 3D model of 35,000 objects textured with bare wood surfaces referenced from the full-scale portion of the set, and stitched scenic textures into a panorama with 3D enhancements. “We developed height curves from topography,” explained Nicolas Aithadi. “We created a sphere, matched the sphere to a tree in the foreground, and then moved that sphere back into the distance until it matched another tree. From that, we calculated the distance between trees, and we kept repeating the process until we had a 3D layout of the surrounding hills. We built geometry from that and projected textures from the plate onto the model. We then used matte painting to fill in about ten miles of terrain from the bottom of the hill to the stadium.” To create atmospheric details, 2D supervisor Marian Mavrovic and his team introduced complex layering of mist through the scene.

For the subsequent Quidditch match, MPC draped stadium geometry with high-resolution cloth simulations, displaying liveries of the teams, and transformed the environment into a snow-covered terrain. “We had the green environment for the trials,” said Aithadi, “and a snowy one for the match. There was no way to apply the snow procedurally, so we took our matte paintings from the trials and hand-painted snow over everything.”

MPC animation supervisor Ferran Domenech doubled as the previz supervisor at Leavesden, and helped plot broomstick action, referencing footage of motorbike races and Formula One. To choreograph Quidditch gameplay, Domenech’s animation team spent approximately six months refining animatics and determining distribution between live and animated elements. “We made it very physical,” said Tim Burke. “We had lots of close-proximity charges and barging between players, with continuously moving cameras that flowed with the game. We wanted to create a dynamic fluid feel to the action, so we relied on our digital doubles a great deal.”

MPC generated digital Quidditch players using a videogrammetry technique. Performers sat in a chair with 60 tracking markers on their faces, and four video cameras aimed at them — one on each side; and two in front, one aimed low, one aimed high. Players enacted the game, emoting as dictated by the screenplay. MPC then extracted animated texture maps of the performer’s faces, painted out tracking markers, and digitally projected faces onto 3D models of the actors derived from cyberscans. “This gave us moving geometries based on the



markers,” Nicolas Aithadi noted. “The textures moved exactly to the movement of the face, with all the detail of blood flowing in their cheeks, and then we used a skin shader to light characters as they moved through frame. It allowed us to get very closeup shots on our digital doubles.”

To assist keyframe animation, MPC shot reference of stuntmen catching balls and taking falls onto crash pads. Animators also rigged a makeshift prop at MPC — a broom with coat hanger attachments — to study balancing on the precarious flying vehicle. “It was important to understand the way it felt to be on the broom,” said Aithadi. “Our keyword was ‘sharp’ animation, with twitches, grittiness, and a lot of subtle movement.”

The animation, combined with videogrammetry realism of digital doubles, allowed MPC to minimize hand-offs between live and CG characters. “They shot pretty much the whole game practically,” observed Aithadi. “Once we had the real footage, we planned where shots would be CG and real, with takeovers in between. While we were reviewing scenes where digital doubles took over from live elements, I started having trouble telling what was CG. So we reasoned, ‘Why spend time doing complex transitions, matching live-action to the pixel?’ We talked with Tim, and decided that a lot of shots we’d planned as takeovers would become full CG shots.” Hand-offs, when required, were streamlined in the bluescreen shoot by tucking in actors’ capes. “It was difficult to control a real cape on set with a wind machine, and very difficult to hand-tweak a digital cloth simulation, so we agreed that on some shots we would add capes as CG. We sometimes ‘cheated’ elements. In one shot, we had Ron full-frame: his head and right arm were real; his left arm, cape, leg and broom were CG — but it worked!”

During winter break, *Harry Potter* visits the rustic Weasley household for Christmas. Celebrations are interrupted by the arrival of Fenrir Greyback (David Legeno), a malicious werewolf in league with the Death Eaters, who attacks the home. Nick Dudman’s team provided prosthetic makeup for Legeno in Greyback’s partially lupine state. The Cinesite model team built a 1/3-scale version of the Weasley Burrow, and collaborated with John Richardson’s effects team to stage a propane-fueled pyrotechnic effect that burned the miniature to the ground. Editorial revisions caused a rethinking of the scene. “The original idea was for Harry and the others to find the house on fire at the end of the sequence,” said Tim Burke. “The revised storyline had Bellatrix Lestrange (Helena Bonham Carter) fly past in her Death Eater form and blow up the house. So we had to craft a new shot to show the house exploding.”

Double Negative rebuilt the Weasley home as a 3D digital model using textures from the practical miniature that Tim Burke’s team had shot as safety clean plates before the pyrotechnic burn. Compositors then used elements of the burning miniature at the climax of a digitally generated supernatural burn. “We used dnSquirt to construct a wall of enchanted fire that the Death Eaters created around the Burrow,” Paul Franklin elaborated. “As Harry and the others breached the firewall, we generated giant serpents of flame that rose out of the fire, keeping them at bay. The

During Christmas break, the Weasley home comes under attack by Death Eaters. The production built a portion of the Weasley Burrow on the Leavesden backlot as a full-scale set, which John Richardson’s team rigged for a propane pyrotechnic burn. The Cinesite model team then built the Burrow at 1/3-scale for a full-building burn effect. An editorial revision, calling for the Burrow to be seen intact before it is set ablaze, required Double Negative to rebuild the structure digitally using textures from the miniature. Artists generated flame effects using dynamic fire simulations.

snakes were quite abstract, but their movement sold their serpentine nature.” Character animators established the underlying motion of the serpents; visual effects then applied secondary dynamics in dnSquirt. “As the snakes reared about, the flames swirled around them, revealing flashes of snakes’ heads. Then, as the firewall built up, Bellatrix fire-bombed the house and left it to burn, which is where we used the miniature.”

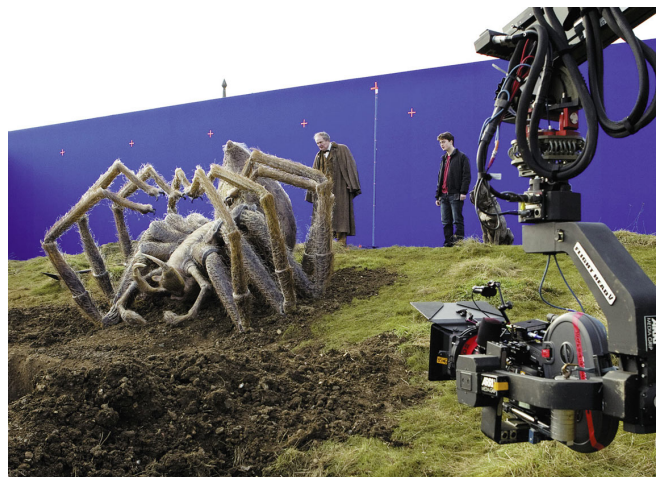
As the Death Eater presence encroaches on Hogwarts, Dumbledore and Harry embark on a mission to destroy Voldemort by seeking a piece of the Dark Lord’s soul hidden inside a talisman known as a Horcrux, in a distant cave. The production shot establishing scenes for the Horcrux quest from a helicopter around the cliffs of Moher, in County Clare, Ireland. “The cliffs were huge,” remarked Tim Burke, “about 700 feet tall. The seas were too big to go out on in a boat, but they were not big enough for our purposes. So we shot stills and motion picture textures on location, shot bluescreen elements of Harry and Dumbledore at Leavesden, and rebuilt the scene as a digital environment at ILM.”



Harry and Slughorn visit Hogwarts’ half-giant gamekeeper, Rubeus Hagrid (Robbie Coltrane), who is stricken with grief at the graveside of his beloved Acromantula, Aragog.

The helicopter plate, circumnavigating a large rock jutting from the stormy sea, served as a guide for camera motion and texture projections. “It was a beautiful plate,” remarked ILM visual effects supervisor Tim Alexander. “Originally, all we were going to do was introduce the cliff into the plate from a separate element shot by Tim Burke. But the ocean plate wasn’t stormy enough and the water simulation was so complex it was easier to create a CG model of the rock, with an element of Dumbledore and Harry, elements of the cliff, a matte-painted sky and a full CG ocean.” ILM fluid dynamics veterans Frank Losasso Petterson and John Hansen leveraged technology developed for the *Pirates of the Caribbean* films. “We used a high-resolution simulation around the rock to create the motion of the biggest wave breaking and water sucking back. We had additional simulations for particles, spray and splash. Then we had our deep-water ocean sim, and the high-resolution sim patched into that.”

For scenes at the cave mouth, Yates shot Radcliffe and Gambon on a set representing a narrow alcove in the cliff face, where Dumbledore opens a concealed door. ILM creature supervisor Michael Balog employed the studio’s rigid dynamics tool, Fracture, to crumble away the rock face. Dumbledore then leads Harry into a vast crystalline cave, filmed as a partial set at Leavesden. “Stuart Craig wanted to create a salt-like crystal cave,” commented Tim Burke. “The crystals had a little bit of sparkle and slight translucency, but they were not shiny, polished surfaces. We wanted it to feel like Harry



The production built crystal structures using fiberglass with a resin-based skin, with subtle internal illumination, backed by illuminated greenscreens. To simulate a magical flare that Dumbledore emits from his wand, the grip and electric team employed a SuperTechno 50 articulated camera crane to puppeteer a China ball lamp high above the set. “The flare flew around causing refractions through the cave,” said Tim Alexander. “We built the cave in 3D because the more We used a crowd tool to populate crystals around the ‘doughnut’ shapes around the columns, and then built crystals.”

ng light source didn't lend itself to a painting.
cave and wrote shaders to sculpt hard-edged
ke up the shapes to make them refract like

Dumbledore collapses after drinking the liquid, leaving Harry to be menaced by a mass of reanimated corpses — known as Inferi — that rise out of the lake. “The Inferi were emaciated beyond anything we could have done with a real person,” observed Tim Burke. “They were based on the look of dead bodies from concentration camps — horrible, but very real. David wanted us to feel empathy with them as they dragged Harry underwater, because they were all victims of Voldemort.” The production used performers wearing greenscreen gloves to pull Radcliffe from the island, and a scuba diver in the water tank at Leavesden to grapple Radcliffe underwater. ILM then generated Inferi digitally, with limited performer reference and zero motion capture. “We tried some early tests to see what it would be like if we had people interact and grab Daniel. But David didn’t feel the performance of a real person gave him the weirdness of the way these creatures moved.”

hadn't gotten as far with the Inferi, so they asked us to produce versions from their designs. Our art director, Aaron McBride, designed all the textures, resembling dead bodies soaked in water, and we made them as humanoid as possible, avoiding zombie behavior. They were very sad and emotional creatures."

To generate masses of Inferi swarming the island, Chu's team hand- animated 80 to 90 characters into a nightmarish, writhing mass. After dragging Harry into the lake depths, Inferi scatter as fireballs rain down. ILM generated the fireballs, seen from underwater, using 3D objects to emit cascades of bubbles. Harry fights his way to the surface to find Dumbledore revived and conjuring the firestorm.

John Richardson's team used practical fire bars on set to generate reflections of interactive firelight on the actors. ILM digital artist Christopher Horvath then used entirely digital fire to choreograph tornadoes of flame that swirled to Dumbledore's bidding. "We started with a three-dimensional particle simulation," explained Tim Alexander. "It had a very low particle count, so we could generate versions very quickly. Those particles acted as 'fuel' to the fire. We then had settings to control how they burned. After a bit of practice, we could visualize how the fuel particles would affect the final simulation, and we could render a bunch in one day to build up the motion of the big twisting wall of fire." 2D supervisor Nelson Sepulveda oversaw layering of characters into the inferno, adding cave and island extensions and interactive light passes. Compositors then adjusted color, contrast, heat haze and levels of fill light, darkening the foreground to cause fire to burn brightly behind characters.

Professor Sepulveda's team (along with others) made use of the plate of the castle from the opening sequence of the film, which was used as a background for the Inferi. The Inferi were created by using a 3D model of a dead body, which was then textured to look like a dead body. The Inferi were then animated to look like they were swimming in the lake. The Inferi were then composited into the scene, and the final scene was rendered.



Voldemort's Dark Mark appears in the night sky over Hogwarts, signifying the Death Eaters' presence and their victory over Albus Dumbledore. Double Negative generated the Dark Mark by adapting a 3D model produced initially for the film's opening sequence over London. Digital artists filled the 3D shape of the underlying skull geometry with vaporous simulations created in Double Negative's fluid system, dnSquirt, and volumetric render tool, DNB. Compositors then layered the roiling clouds over a background plate of a grassy slope shot at Leavesden and a digital matte painting created from plates of the castle miniature.

Harry and Dumbledore return to Hogwarts to find Death Eaters in the castle's astronomy tower. For the tower exteriors, José Granell's team built a 1/10-scale miniature. Stuart Craig built a full-scale tower interior at Leavesden, surrounded by greenscreen. Double Negative then generated 360-degree panoramas of the surrounding castle and its scenic environs. The setting served as the stage for a showdown where Defense Against the Dark Arts Professor Severus Snape (Alan Rickman) defeats Dumbledore in wand combat, causing Dumbledore to fall from a parapet to his death.



Looking out from Hogwarts' astronomy tower, Hermione Granger (Emma Watson) consoles Harry Potter after the traumatic events of their sixth year at Hogwarts. David Yates filmed Watson and Radcliffe at Leavesden, in a full-scale tower set backed by greenscreen. José Granell's team then built a 1/10-scale miniature of the tower for exterior views of the castle spire. Double Negative combined the live plate with 1/10-scale and 1/24-scale castle elements, and layered the background with digital geometry and matte paintings of Hogwarts' lake and its environs.

Gambon performed Dumbledore's death by stepping into a bluescreen rig. "Sir Michael stood back into the rig," related John Richardson. "That held him safely upright at the right attitude to the camera, so he could lean back and perform his fall. We blasted him with air from behind using every air mover and blue wind machine we could get our hands on. David filmed him at high speed, and tracked the camera back, simulating the fall." Double Negative composited the background plunge toward a stone courtyard, based on textures of the Hogwarts miniature and a full-scale Leavesden set.

Snape and the Death Eaters escape, leaving a path of destruction in their wake as Bellatrix Lestrange gleefully throws out wand blasts. Cinesite generated an effect, conceived in postproduction, shattering the windows of Hogwarts' Great Hall. The explosive effect was accomplished by shooting textures of the set, and then using those stills to build geometry of the hall with dynamic simulations of flying glass, tumbling furniture and floating candles snuffed out in the blast. "José Granell explained to us how he would have achieved the effect practically," stated Cinesite 3D supervisor Ivor Middleton. "We applied that to our animation through a series of multiple explosions. For each window, there were a series of staggered detonations; then we added debris from virtual gas cannons exploding in. We set off 90 explosion events over four seconds. Andy Robinson's 2D team then layered each explosion with refraction, specularity, dust and debris to make a very physical-looking event."

Bellatrix next destroys the rustic hut belonging to Hogwarts' half-giant gamekeeper Rubeus Hagrid (Robbie Coltrane). John Richardson's team rigged the hut's detonation as a pyrotechnic event filmed at night against greenscreen on the Leavesden backlot. RSP provided wand effects, scale-enhancing composites of Coltrane, and background panoramas built from Scottish scenic textures, the castle miniature and the animated Dark Mark, which Double Negative generated over Hogwarts.

Yates then introduced a new concluding scene, conceived with J.K. Rowling's approval, in which Hogwarts' Deputy Headmistress Minerva McGonagall (Maggie Smith) rallied students in the courtyard to dispel the Dark Mark. "It was quite a poignant moment," said Tim Burke. "McGonagall led all the children to raise their wands, and they sent up a spell to break up the Dark Mark. It

replaced Dumbledore's funeral scene from the book, which at one point we were all set to do. It came back to the fact that David was more interested in drama than action. It was performance-led, emotional, and very powerful."

Double Negative generated the Dark Mark destruction, reworking the apparition's base model created for the film's opening scenes. "We re-lit the model for night and placed it in a big boiling cloudscape," said Paul Franklin. "As the light from the wands began to affect the skull, we introduced light inside it, illuminating the volume of the clouds. That was tricky because our earlier scenes had been geared toward making the Dark Mark look good in daylight. A lot of work went into the compositing to get layers of light to build up inside the skull, cracking along fissures that related to the way sutures between parietal bones fit together in a real skull. The Dark Mark then dissipated into the cloudscape, the Death Eaters driven away by the children and teachers at Hogwarts."

The film concludes with Harry, Hermione and Ron contemplating their uncertain futures as dawn breaks over the astronomy tower and Dumbledore's pet, Fawkes the Phoenix, flies away, animated by Framestore. The adaptation, although not slavish to the events of Rowling's novel, captured the intent of the penultimate volume and set the stage for the grand finale still to come. "It has been a very enjoyable experience," commented Tim Burke, who remained energized and optimistic halfway through production of the first half of a two-film adaptation of *Harry Potter and the Deathly Hallows*. "We've got a huge task ahead of us, but the first part is looking great, and the second is going to be phenomenal. I think there will be more than a few words to write on that one."

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Heavy Metal

ARTICLE BY JODY DUNCAN

Michael Bay's 2007 monster hit, *Transformers*, ended with teenager Sam Witwicky (Shia LaBeouf) and his new girlfriend Mikaela Banes (Megan Fox) having survived being swept up in an eruption of hostilities between two races of robotic aliens: the peaceful Autobots and the evil Decepticons. At the opening of Bay's sequel, *Transformers: Revenge of the Fallen*, the Autobots have since gone undercover, working with a covert military unit called 'NEST,' while Sam and Mikaela have attempted to return to normal lives. But Sam's plans for normalcy — which include going away to college -- are disrupted when the Decepticons declare all-out war on the Autobots, NEST and the citizens of earth.

At his Bay Film offices, the director worked with previz artist Steven Yamamoto and his crew to design action sequences that would deliver even more bang than those in the previous film. Bay also upped the ante for Industrial Light & Magic and Digital Domain, which would generate visual effects that were both flashier and subtler than those in the original. "The easiest shots on this movie were equivalent to the hardest shots on the first movie," noted Wayne Billheimer, visual effects producer at ILM, which would contribute the majority of the show's 1,600 effects shots. "We took a big step forward from where we had left off. The first movie had 11 robots in it, and this one had 60, total — 46 that we did, and another 14 that Digital Domain did. This movie required 140 terabytes of storage, whereas the first movie had needed about 20 terabytes. In every respect, this movie was considerably more challenging."

"The numbers were higher for everything this time around," ILM visual effects supervisor Scott Farrar agreed. "We had huge model and paint and animation crews. Each robot took 12 to 15 weeks to build, and then at least that or more to rig. It would be 25, 30 weeks before we were ready to put a robot into a shot. With 40-plus new robots, that was a lot of hours." Contributing to the complexity and size of



In the sequel to Michael Bay's 2007 hit, Transformers, teenager Sam Witwicky (Shia LaBeouf) is drawn, once again, into the age-old war between giant alien robots, the Autobots and Decepticons. Bay assigned the majority of the effects in Transformers: Revenge of the Fallen to Industrial Light & Magic, with significant support provided by Digital Domain and other vendors. Bay raised the bar for all of the visual effects teams by including many more robots, and more closeups on those robots, than were in the original film. The sequel also featured major sequences shot in high-resolution IMAX format.



After spending months previsualizing the film, Bay and his production crews shot location sequences overseas, at iconic sites in Egypt and Jordan, and within the United States, at urban and wilderness areas in Pennsylvania, California and New Mexico. The desert near Lone Pine,

the show was the fact that two major sequences would be realized in the high-resolution IMAX format. “Rather than shoot on 35mm and bump it up, we actually shot these sequences on 70mm IMAX cameras. IMAX is eight times larger in frame size than an anamorphic frame; and so, for us, that meant more render space, more resolution, more time to make the renders. Just managing the show, which fell to our digital production supervisor, Jason Smith, was a major feat unto itself.”

California, served as the setting for a prologue sequence, circa 17,000 B.C., in which human primitives encounter a hostile Decepticon leader named the Fallen, one of nearly 50 highly detailed CG robots ILM created for the film.

Due to the large number of assets that would have to be built, modeling and texture supervisor Dave Fogler was among the first crew members at ILM to start work, launching the project in February 2008 with a trip to production designer Nigel Phelps’ art department, the walls of which were covered with artwork by Ben Procter and Page Buckner. “We walked in there,” Fogler recalled, “and there were rows and rows of robots illustrated on the walls. Some didn’t end up in the movie, of course, but a lot of them did. When we came home, we hired a lot of people. At our peak we had 25 modelers and painters, and we stayed at that number for about a year.”

A hard lesson that ILM had learned on the first Transformers was that Michael Bay preferred robots that looked like they were made of real-world, relatively low-tech mechanical parts, rather than fantastic, futuristic mechanisms. “Back on the first movie,” said Fogler, “nobody really knew what these robots should look like. Because they aren’t from earth, they could have had alien insides with fantasy mechanics, and we went down that road for a while. But at a certain point, Michael had said: ‘They don’t look real. Everybody knows what an engine looks like when they open up their car hood. We need to tie these things to the real world by stuffing them with real, recognizable mechanical parts.’ So we started frantically making a parts library — springs and gears and hoses — and stuffed all these parts into the robots. Not only did that help to sell the robots as real, it also helped with scale. You could tell how big a robot was in relation to a carburetor or spring. It was an attempt to fool the eye into believing it was real through absurd mechanical complexity.”

For the sequel, the model department’s first order of business was to build a much more extensive library of real-world parts. Modelers would then assemble their robots from those parts — a CG version of model kit-bashing. “I come from the ILM model shop,” said Fogler, “and there was a long tradition of kit-bashing there. We’d walk up to the loft where there were cartons of model kits, dig around and find what we needed for building and detailing our models. This was the same idea. We wound up with easily a thousand parts — every little screw and gear and spring — all textured and plugged into this library. Our first robot took a long time to make, because we were building everything from scratch; but as the show went on, we were able to work faster because everybody had access to everything that had been built and could use it in their models. That’s not to say that the later robots built themselves. There was a lot of custom work for every robot; but when we got down to making the elbow, there was no need to make all-new elbow bolts. They were right there in the library.”

The model crew continued its construction of robot parts as Bay and his production team shot the film on locations around the world. The desert outside Lone Pine, California, served as the setting for a prologue, set in 17,000 B.C., in which human primitives have an encounter with a Decepticon

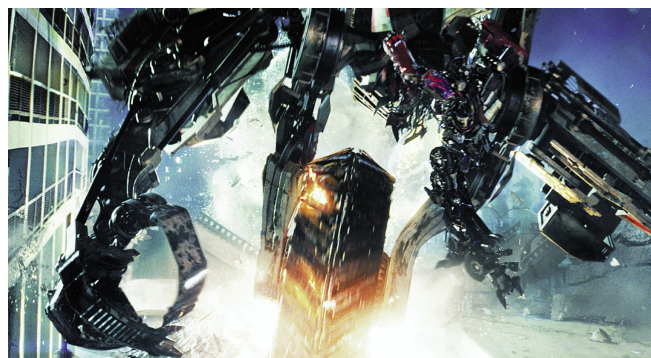
leader, called the Fallen. In his initial visit to the production art department, Dave Fogler had noted that the illustrations of Fallen were more organic-looking than the other robots; and so, rather than assemble Fallen from the mechanical parts library, the model crew first sculpted the character's form. "Fallen looked more alien," noted Fogler, "as if he was made up of pieces that weren't real-world. So I took the approach that we could treat him as a creature, sculpt him as a single mesh and then cut that up into little bits. That approach didn't really work, though. As it turned out, Fallen wasn't all that different from the other robots. Even though he is curvier and more organic, he is still made up of thousands of little hard-surface models. By the time we were finished, Fallen looked like a big cast-iron skillet, with pits and burnished edges."

To accommodate closeups — which would be more numerous and more lingering on this show than on the last — the model and paint team detailed facial areas of the robot models to a very fine degree, building them out of hundreds or thousands of small parts. Many movable parts also gave the animators the flexibility they needed to create expressions on faces made of hard metal surfaces.

"With metal," said Fogler, "we can't stretch things or envelope stuff or provide smile shapes on a single mesh. All we can do is add a lot of small rigid pieces that the animators can move to create expressions. Fallen fell into that camp. He needed many little pieces of interesting bits of metal that could be composed into a mouth or expressive eyebrows."

"A huge amount of the character's performance is delivered through the eyes," added animation supervisor Scott Benza who, along with associate animation supervisor Rick O'Connor, supervised a team of 54 animators — nearly three times the number on the original film, "and so a lot of attention to detail was given to the eyes and how they would articulate. All the 'muscles' around the eyes had to be represented by individual metal pieces. We had to make sure that the robots had some representation of a brow, a lower lid and cheeks, so that their eyes could open wide or squint. In addition to giving them eye movement similar to what you'd see in a human character, we also gave them some robotic types of eye articulation, like mechanical spinning and dilation."

ILM viewpainter Jean Bolte provided more detail and variety in the Fallen model, painting a shimmering lapis lazuli blue in some areas, such as the fins on the side of his face. "Jean painted that color throughout the model, almost making it look as if he was in military dress uniform," said Dave Fogler. "Fallen also had a lava-like glow inside, and so Jean painted heat discolorations on him, like you would see on a motorcycle exhaust pipe, to make him look hot. Adding that color design on top of the cast-iron skillet aesthetic created his final look."

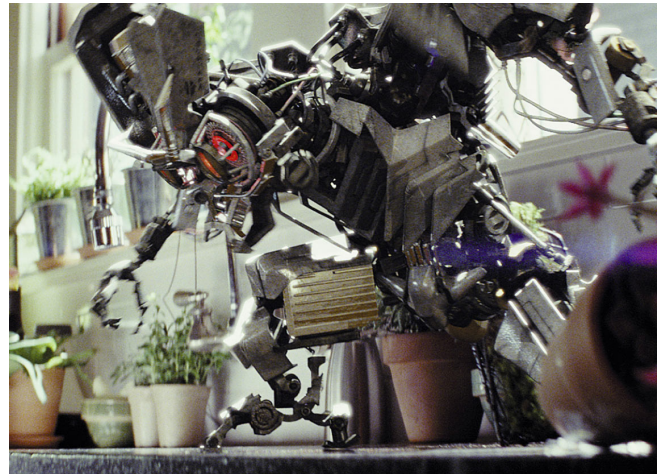


The prologue gives way to modern-day Shanghai, where the fabricated report of a toxic waste spill provides cover for the evacuation of the city due to Decepticon attacks. Michael Bay and ILM visual effects supervisor Scott Farrar shot the Shanghai sequence at a decommissioned steel foundry in Bethlehem, Pennsylvania. The vastness of the steel plant, which had sprawling structures with 100-foot-tall smokestacks, provided an ideal environment to sell the scale of the robots. The ILM digimatte department inserted skyscrapers, filmed in Long Beach, California, into the far backgrounds of shots, and added colorful neon signage in the Asian style.

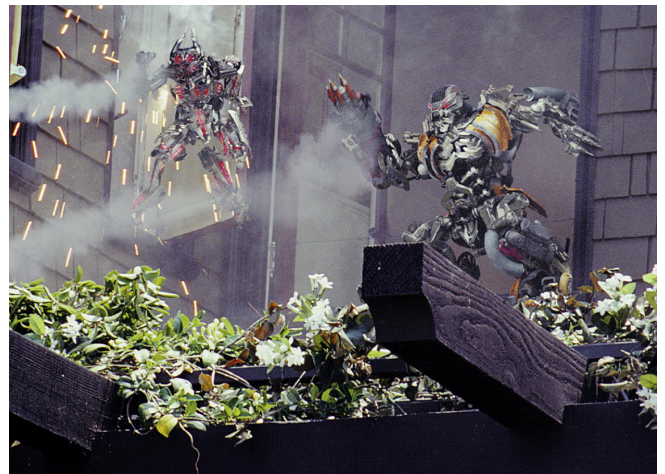
The prologue gives way to the modern-day story, which opens in Shanghai, where a reported toxic waste spill provides cover for the evacuation of the city due to Decepticon attacks. Bay and his production crew shot the Shanghai sequence at a decommissioned steel foundry in Bethlehem, Pennsylvania. “The steel plant was several blocks long,” recalled Scott Farrar, “with 100-foot-tall smokestacks, an environment that really helped to sell the scale of the robots. Duncan Blackman was my on-set layout artist, and he put out little balls and markers and poles to represent the robots on the set. All the skyscrapers and other buildings in the background were actually shot in Long Beach; and then our digimatte department, led by Richard Bluff, added signage in the very colorful style of buildings in Asia.”

The Shanghai scene reintroduces Optimus Prime, the transformer hero of the first film. ILM refined the model considerably to accommodate closeups and the greater resolution demands of IMAX. “We added layer upon layer of fine detail to the Optimus model,” said Dave Fogler, “right down to smudges of grease and nicks on top of individual bolts.” The upgrade also filled in areas that had never been entirely fleshed out for the first film. “It was almost comical — we would get a shot and find that an entire underside of Optimus’ arm was unpainted. And we’d think, ‘How did we get through the first movie without ever showing the underside of his arm?’ You take these guys to 80 percent, whatever you actually need for your shots, but you never completely finish them. You could work on these robots for the next 100 years and never finish them!”

Though the character’s animation rigging needed little upgrading, Optimus animation benefited considerably from improved tools used to assist those rigs. During shot production on the first film, animators had worked with full-resolution CG characters, which meant long save times, especially in scenes featuring more than one robot. “It would take an hour or more to write all that information to disk,” recalled Scott Benza. “On the new movie,



Packing to leave home for college, Sam drops a splinter from the Allspark cube, which lands in the Witwicky kitchen and brings to life an array of small appliances. Digital Domain realized the ‘kitchen bots’ – including an espresso machine – under the supervision of Matthew Butler. Lighting artists remapped high dynamic range images to re-create the set in Nuke, which enabled them to recapture the HDRI from any point of view as the CG appliances moved through a scene. Digital Domain integrated the kitchen bots into live plates, tweaking animation timings to correspond to on-set effects gags.



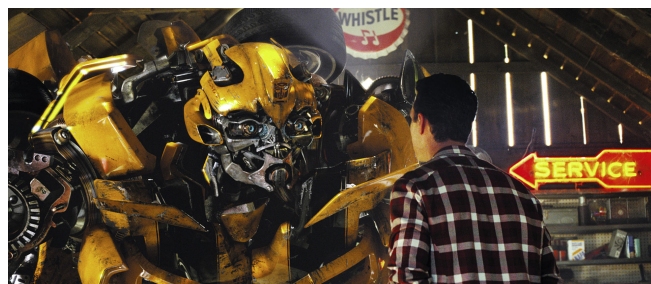
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each character had five to seven different resolutions that we could work with at any given time. So you could work on the detail of just one character in a scene, at higher resolution, and all the other characters in the scene could be at much lower resolution, which enabled us to save the scene quickly. It was almost like working in real time, which was a huge step forward. All of the bots from the first movie were upgraded to have that multi-resolution process run on them, which was a big deal to do, initially; but I don't think we could have done the movie at the level of quality we delivered without that capability."

For Optimus and other transformer characters, the animators had video reference of the voice performers delivering and recording their lines. But how helpful that reference was depended entirely on the character and the scene. "Michael had a very specific idea in mind about how the characters should act in these scenes," remarked Benza, "and it often wasn't what the actors were doing in the video. But if we found ourselves in a pinch, wondering what Optimus Prime's mouth should do to make a certain sound, or what his facial expression should be on a particular piece of dialogue, we would refer back to what Peter Cullen, the voice actor, had done."

The Shanghai sequence features the first of many transformations in the film. Initially, Michael Bay had decided he would spend less time on transformations in the sequel, his logic being that they had already been well established in the first film. However, as production wore on, he changed his mind. "Michael did a 180 on that decision," said Benza. "He'd say, 'You know, this movie is called 'Transformers' — we need more transformations!' So we added a lot more of them." As before, animators executed transformations that looked somewhat plausible, with many robot parts corresponding to parts on the vehicles from which a character transformed. Creature TD Keiji Yamaguchi became ILM's resident transformation expert, designing and handling the majority of the transformation shots, which were typically hand-animated. "We would start by scrunching the robot into the most compact form of the vehicle that it was being transformed from, and then we would come up with a cool way to go from that into robot mode. Finally, we'd go back and find paths of action for each individual part of the vehicle to robot. No two transformations were alike."

From the chaos of the Shanghai sequence, the story cuts to the Witwicky home, where Sam is getting ready to leave for college. As Sam packs, a splinter from the Allspark cube — the source of life energy for the alien robots — falls out of a jacket pocket, burns through the floor of his room and lands in the kitchen, bringing to life appliances such as a blender, toaster, router, microwave, espresso machine and garbage disposal. Digital Domain realized the kitchen bots, under the visual effects supervision of Matthew Butler and the animation supervision of Dan Taylor. "This was a one-off sequence," said Taylor, "so there wasn't a lot of time to establish the kitchen bots'

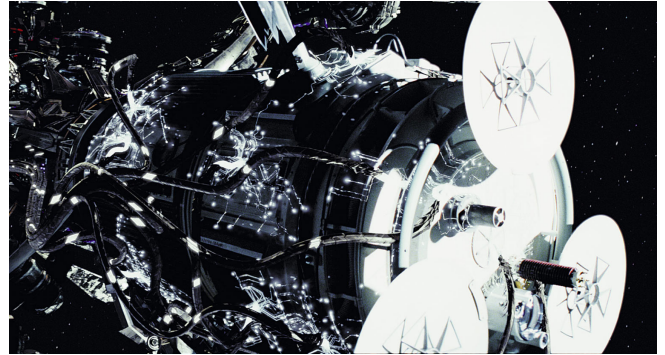


ILM made slight cosmetic changes to Bumblebee – Sam's Autobot sidekick – to accommodate the sequel's newer-model Camaro from which it transforms. The original model held up well in terms of rigging and structural integrity, however. As the only major Autobot character incapable of speech, Bumblebee had to deliver an expressive facial performance, achieved via the keyframe manipulation of hundreds of small mechanical parts to simulate frowns, smiles, and eye and brow movement. ILM rendered Bumblebee, and all of its CG robots, according to the dictates of Michael Bay, who wanted the robots lit beautifully and well, even if that meant deviating from strict photorealism.

characters; but we figured out how they would behave based on what they were. The garbage disposal, for example, had garbage flying off of him as he ran around. Michael Bay got into a little toilet humor for the espresso bot, having it fart flames behind it as it runs down the hall. For all of these smaller, comic-relief bots, we had to look for those little moments and bits of business that would make their brief time on screen special, memorable and funny. The kitchen bots had a bit of a classic cartoon feel, but we had to find the balance between cartoony and the world of Transformers.”

Animators integrated the kitchen bots with live-action plates that included interactive special effects gags. “Getting the kitchen bots to time up with all the different practical elements on the set was a challenge,” commented DD compositing supervisor Lou Pecora. “There was a lot of interactive stuff that we added, as well. For example, the stuff thrown up by the garbage disposal — what we called the Garburetor — was a fluid sim. We also shot some new practical elements, and rescued others from the plate. So it was a combination of practical and CG.” Another challenge in the kitchen bot sequence was tracking to fairly wide anamorphic plates. “We had to warp our CG to match the plates. In a lot of cases, the edge of frame is where tracking falls apart; and in some of these shots, we had the kitchen bots on both ends of the frame at the same time — in all four corners at the same time, in some cases — so it was grueling to get the tracking to work and get everything to stick. And of course, we had to match the lens aberrations and the chromatic separation where the red, green and blue channels split apart in CG, as well. It was traditional 2D work, but there was a lot of it, and it was pretty unforgiving.”

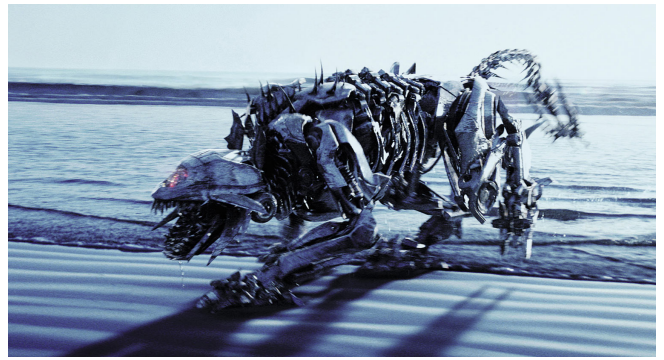
Digital Domain made significant lighting improvements for the kitchen bots and other CG characters in enclosed environments, using high dynamic range images in a slightly different manner. “It was based on our regular pipeline,” explained DD lighting supervisor Charles Abou Aad, “but we took it a step further, remapping the HDRs out to a wideframe representation of the enclosed space where the CG characters were. Any time there was an indoor environment, we would re-project the HDRs and re-create that environment with simple geometry, in Nuke. Once we’d done that, we could recapture the HDR from any point of view, wherever the characters were in the room. We weren’t restricted to using HDRs that were taken on set, the way they were taken on set. We were able to almost revisit the set and get our lighting cues, moving around with the characters as they moved through the set. It’s rare to have the time to reconstruct a set inside of Nuke and then recapture the HDRs. Normally, with any HDRs shot on set, you end up using the coverage from that specific point of view. That yields decent enough results, but this was better.”



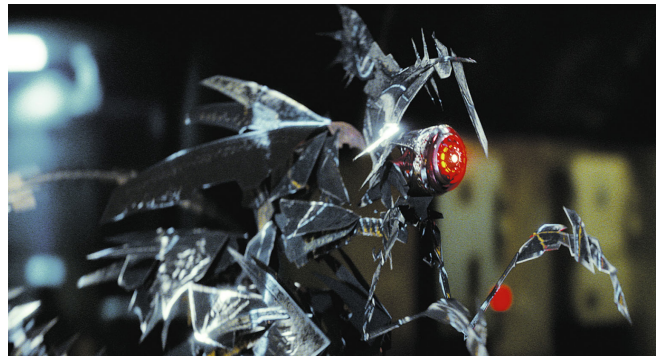
The Decepticon Soundwave intercepts communications at N.E.T – a secret military unit working in collaboration with the Autobots – by infiltrating a satellite in space. The Digital Domain shot has the non-anthropomorphic Soundwave spawning organic tentacles that connect to the satellite and then transform to suggest a geometrically patterned circuit board. To save production time, yet fulfill Michael Bay’s request that Soundwave look as if it was made up of many different materials, Digital Domain broke up the character’s lighting into separate rendered layers, enabling quick adjustments in the composite.

Digital Domain gave ILM rendered kitchen bot elements for a shot in which Bumblebee — Sam’s Camaro-transformed sidekick and an ILM creation — rolls out of the garage to shoot down the pesky creatures. ILM had to make a few cosmetic changes to its original Bumblebee model to accommodate a newer model Camaro with slightly different hubs and headlights; but, mechanically, the original Bumblebee model held up very well. As the only Autobot incapable of speech, Bumblebee had to deliver an expressive facial performance, particularly in an emotional scene in which Sam explains that the bot cannot accompany him to college. “We had to depend heavily on Bumblebee’s face and eyes to deliver the performance,” noted Scott Benza, “as well as his head and body movement. When Sam tells Bumblebee that he’s going off to college without him, you can really see the heartbreak on his face.”

The shot of Bumblebee rolling out of the garage illustrated a philosophy that would guide both Digital Domain and ILM in creating their shots: Michael Bay wanted to see the robots, and he wanted them to be lit beautifully and well — regardless of the dictates of absolute photorealism. “Everybody wants to go out, record the lighting on the location or set, and plunk that down onto a character,” said Scott Farrar. “We did, of course, have to record each and every camera location and lighting setup so that we could create a reflective sphere and get our base lighting. But I can’t think of a single shot where we didn’t go back in and augment the lighting, just like a DP would do. A DP doesn’t just put actors in front of the camera without finessing the lighting. He might block out the sun and put an artificial light out there. He might want more backlight or more of a beauty light or more light on the eyes — that’s what you do with glamour photography in films. And that’s what we did on the robots. We had the set lighting as a starting point, but we reconfigured it a lot. In virtually every shot we added lights and shadows, changed the color temperature. Sometimes we completely ignored the angle of the key in the plate — so the global illumination didn’t do me any good there.”



Information gleaned from the satellite intercept leads to Decepticons learning the whereabouts of an Allspark shard, heavily guarded at a naval facility. The Decepticons deploy the cat-like Ravage robot to help retrieve the shard. ILM’s model and paint crew created detailed textures, adding scratches, chips and weathering to Ravage’s metal exterior to suggest a battle-worn character. ILM modelers built and rigged the digital model at the front-end of the production schedule to give animators ample time to work out the character’s part-feline, part-mechanical movements.



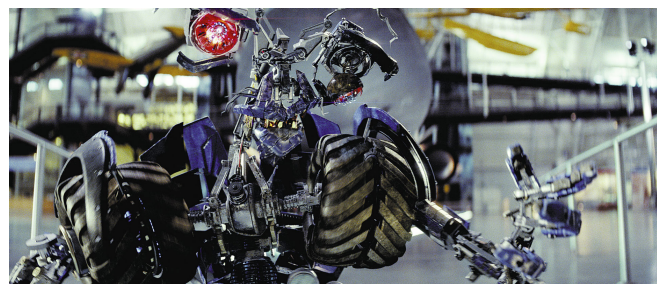
Ravage disgorges tiny metal spheres, which spill into the room where the Allspark shard is held. The ball bearings then transform into microcons that swarm together to form ‘Reed Man.’ Digital Domain re-created the physical set as a virtual environment to tweak a 360-degree camera move and maintain the position of Reed Man in frame. To add visual interest to the character – which was comprised entirely of flat planes – Digital Domain modelers first built Reed Man as a thicker model with geometric detail. Artists baked surface detail and lighting onto that model, then flattened the geometry.

“It was fascinating to watch the way Michael works on set and then try to apply those principles to our CG work,” added ILM visual effects co-supervisor Jeff White. “On set, they would get the basic sunlight or environment light first, but then they would add little lights all over the characters, kicking light off of reflector boards and all kinds of things. When we start a shot it is all about gathering on-set data and building our environments so it’s a perfect match and our characters will fit right in. But what Michael pushed us to do was say, ‘Okay, that’s a great first take, but don’t be afraid to start putting in more lights, or unmotivated lighting.’ We created packages for our lighters so they could do the same thing in CG that Michael had done on set.”

“Michael Bay is very hot on lighting,” Matthew Butler agreed, “and he thinks practically in terms of lights and lenses and cameras. So that’s where you start with him; but he also likes to show off stuff. He doesn’t like to feel as if he’s paying for something you can’t see. So we were always straddling that line between photorealism and making the robot look really sharp. It was a line between integrating our elements seamlessly into the photography and making them stand out. Where we would normally de-focus a CG element commensurate with the plate, Michael asked us to make things sharper than the plate. What I learned on this show is that we are perhaps overly cautious about integrating CG with photography and making it look absolutely real. It may be that the general public is less discerning about ‘real’ than we are. Michael forced us to deviate from reality here and there, but that just meant our shots had to be that much better in every other aspect.”

Bay’s directive that the robots appear crisp and sharp in shots also led the visual effects teams to minimize motion blur. “You want a certain amount of motion blur,” stated Scott Farrar, “but I think the mathematical rendering of motion blur doesn’t look exactly right. When the motion blur setting is normal on sharp objects such as robots, they look so blurry that it’s hard to read them. So, in this film, we cranked motion blur way down, to half or one-quarter normal for, say, a closeup on Bumblebee when he rolls up from the garage, so we would see his face very clearly. And then, when he started moving again, we cranked up the blur. We were fiddling with motion blur on every shot. People tend to oppose changing those motion blur settings, so in dailies everybody would say, ‘No, no!’ But Michael would come in, and say: ‘It’s not sharp enough. You’ve got to make the robots sharp.’ So I came up with these formulas for reducing motion blur. We got on the Ray Harryhausen bandwagon — no motion blur! Or very little.”

The narrative cuts from the domestic drama of Sam’s departure for college to N.E.T headquarters, where Optimus warns military brass that the Decepticons have increased the frequency and ferocity of their attacks. The N.E.T base includes a hangar where Optimus and other Autobots are parked between missions. Among them are the ‘twins,’ jive-talking bots that transform from small candy-apple red and shiny green cars and provide much of the movie’s comic relief. The twins were the first robots completed by ILM’s modeling and paint



A small Decepticon posing as a remote control toy truck searches for the Allspark splinter that Sam has given to Mikaela Banes (Megan Fox) for safekeeping. Digital Domain’s ‘Wheelie’ evolved throughout production, changing from a sad, almost lovable character to a crude, Jersey-accented tough guy. For the scene in which Wheelie

crew. “We had nailed the high-gloss look of a car paint finish in the first film,” said Dave Fogler. “Both twins had metallic paint breakup in them; and the red one had an opalescent look, with highlights that changed from orange to yellow. The TDs had to work out shaders for all of that, which was tricky.”

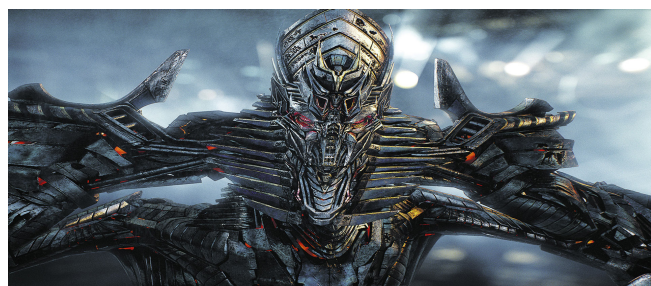
searches Mikaela’s chop shop, on-set crews puppeteered props to suggest the robot’s interaction with cigar boxes and other items in the environment. To paint out puppeteers and rigs, Digital Domain thoroughly captured the set in digital stills and rebuilt parts of plates as needed.

Decepticons intercept communications at NE.T when Soundwave, another Digital Domain creation, infiltrates a satellite in space. “You don’t see Soundwave actually transform,” said Matthew Butler, “but you do see him connect to the satellite in an interesting manner. He’s like a big spacecraft, very geometric and mechanical; then he spawns organic tentacles, rendered as metallic bundles of fiber optics. When they connect to the satellite, they change to a more geometric pattern, akin to the look of a circuit board. There was a nice mix of behaviors in that shot, a combination of procedural and hand animation.”

The Soundwave shots were among the last to be turned over to Digital Domain, requiring the effects team to come up with some time-saving techniques. “Michael wanted that character to look like it was made up of many different materials,” explained Lou Pecora, “but that was difficult because we only had about six weeks to do these shots. To save time, we broke the lighting out into layers in the render so we could make quick adjustments in the comp. Having various passes from the renders gave us a lot of flexibility and control, and we would never have finished those shots in time without that.”

The flexibility afforded by splitting the lighting into separate layers came with a price, however. “There is always the double-edged sword of flexibility versus confusion,” Butler commented. “A compositor wants the ability to make changes in the composite — to change the ambient occlusion, for example, or the specular reflection, or the depth of field. That’s the up side. The down side is that it is complicated and laborious and tricky to track. In addition, by giving the end user the ability to affect light, you put the onus on that artist to essentially become the renderer. It is nice to have a render that is all in one, that looks great just using all the mathematics and physics that are inherent in the application itself. Once you start pulling those things apart to give yourself flexibility, it puts more of a burden on the person who has to pull it all back together. You’ve got the ability to tailor it, but you’d better get it right!”

Decepticons learn from the satellite intercept that the Allspark shard is heavily guarded at a naval facility on Diego Garcia. To retrieve it, they send out a cat-like bot named Ravage — one of ILM’s assets. “Ravage was in the original Transformers cartoon,” observed Jeff White, “and we were excited to see him in this movie. He has a metal exterior, but he’s pretty beaten up, with a lot of scratch marks and textures. There are a couple of scenes that are really close on his teeth and head, where you can see all the detail we put into his paint and geometry — all the chipping, scratching and weathering.” To give the



Fallen monitors Decepticon attacks on earth from the Nemesis spaceship, concealed behind Saturn. To add more detail and texture to Fallen’s essential cast-iron skillet look, ILM viewpainter Jean Bolte painted some areas of the model with a shimmering lapis lazuli blue, creating the look of a military uniform. Bolte also painted discolorations – like those on a motorcycle exhaust pipe –

animation department ample time to work out the character's part-feline, part-mechanical movements, ILM modelers built Ravage at the front end of the schedule. "The animators jumped in with early tests just using cat reference, and they got some pretty fantastic results. If you look at Ravage's animation, there are a lot of signature cat moves in there, such as the way a cat will swat at a toy."

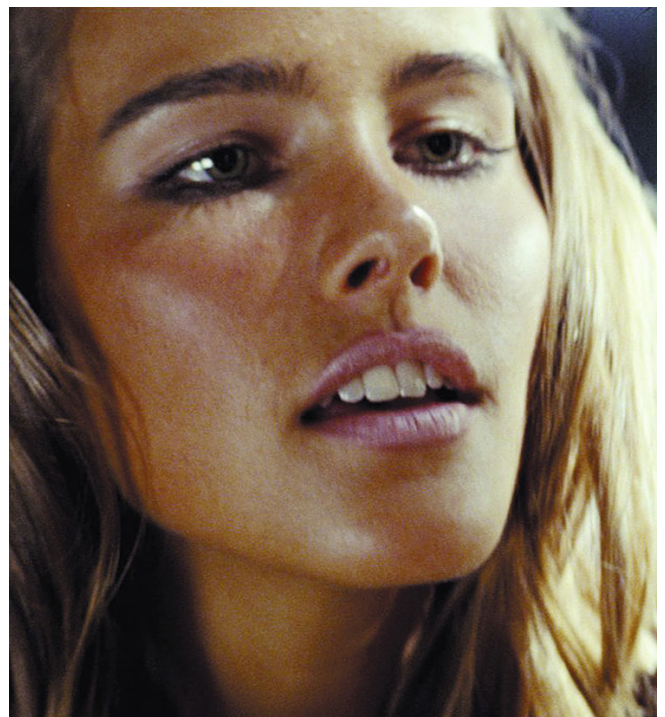
on Fallen surfaces to suggest heat emanating from his glowing core.

To gain Decepticon entry into the area where the Allspark shard is held, Ravage vomits thousands of tiny metallic spheres into a pipe. The ball bearings spill onto the floor of the sealed room and transform into microcons that begin to swarm and form a shape. "The impression is that each of these thousands of little bugs has intelligence," said Matthew Butler, "and yet the swarm also works like a hive of bees. Michael set the tone of this early on by photographing ball bearings on a set at Digital Domain. He had these big magnets underneath a table, and he moved them around to make the ball bearings behave in a very staccato, skittish way. That footage sets up the scene, and so we had to come up with animation and a procedural system to emulate that look. We needed procedural tools to handle thousands of these things; but we also needed to be able to hand-animate them because in some shots they were going to be full-frame, 20 feet high on the screen."

Digital Domain realized the shots using a particle simulation crowd pipeline in Houdini. "We set up a particle system with a set of rules the little spheres would follow," noted DD CG supervisor Paul George Palop, "which was similar to the rules of physics that were at work with the ball bearings and magnets that Michael Bay had shot. We gave the particles charges so they would repel each other, and we tracked that motion in their ball-bearing form. Once they turned into the microcons, they exhibited more controlled behavior, with some robots walking in one direction and others walking in another. For that, the animation department gave us walking and other cycles we could run in the crowd system."

The microcons then form into 'Reed Man,' a razor-thin robot. "This was our most difficult shot," stated Matthew Butler. "It is like a 360-degree Steadicam shot, orbiting around as Reed Man is formed from thousands of these little robots. That, again, was something where we had to dovetail hand animation and procedural animation."

"We worked on that shot for months," Paul George Palop added. "We started by simulating particles filling up a volume that ended up looking like Reed Man. That turned out to be a very challenging problem because just using straight particle simulation wasn't giving us the right behavior. They needed to move upwards and do all kinds of specific things, but it was very hard to get that kind of control with the particle simulation." Digital Domain finally got the look by running a rigid body dynamics



simulation in reverse. “The particles were actually falling down; but by running it backwards, it looked as if they were flowing upward. It was easier to control that and to determine where each particle would go to form Reed Man.”

Michael Bay wanted to retain as much of the original 360-degree plate as possible, but Digital Domain had to re-create the set as a virtual environment to make the shot work. “When they had shot it,” Palop explained, “there was no reference object there — no robot, of course — and so, they just did the best they could. But, eventually we had to create a virtual set and tweak the move so we could accommodate the robot. The environment was re-projected back onto geometry, and we had to build a CG floor as well. It was an interesting challenge because even though it was just a simple revolve, the scale of these things was so small, moving the camera even an inch would move the whole world. So we had to be very careful how we moved the camera and how close we put the micro-robots in front of the lens. To help with scale, we gave the shot a very shallow depth of field, as if the tiny robots were shot through a macro-lens.” Compos-itors adjusted depth of field in the composite, which allowed for faster shot turnarounds.

The final Reed Man is so razor-thin, he virtually disappears when oriented a particular way to camera. “It was a challenge to figure out how something like that would move,” said Dan Taylor. “We knew from the mood of the sequence that he had to be creepy and sinister at first; but then, when soldiers come in and all hell breaks loose, he had to be really fast and agile as he runs away. In the original design, Reed Man had very short back legs; but when we tried to animate a model based on that design, it looked like Reed Man was doing that Fred Flintstone bowling thing on his tiptoes whenever he moved fast! So we had to extend the back legs, and make the front legs shorter, somewhat like a praying mantis.”

No aspect of Reed Man was more problematic than lighting, due to the inherent difficulties of making a flat plane look interesting. Reed Man was made up of nothing but flat planes. To work around the problem, Digital Domain modelers first built the model with some thickness and volume. “The original model had diameter and geometric detail,” said Charles Abou Aad. “We baked all of its surface attributes onto that thick model, and then we flattened the geometry. So what you’re seeing at the end is flat geometry, but the lighting on it reacted as if the model had some thickness to it. That gave us nice variation and highlights. We also played with shading on every individual blade,

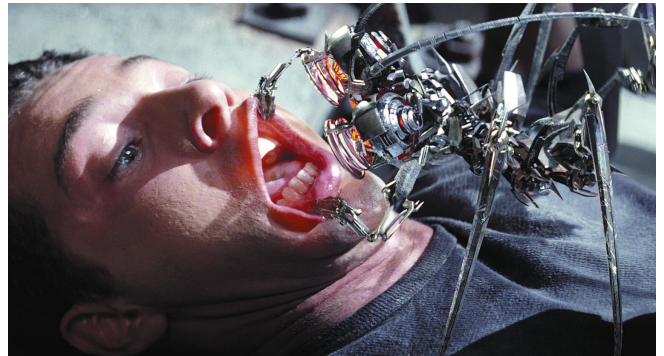
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Sam is captured by the Decepticons and interrogated in a warehouse by Megatron. A major character in the first Transformers, Megatron went through a significant redesign and remodeling at ILM to accommodate closeups and the higher resolution required by the IMAX format. The new Megatron featured legs with track treads running through them, as well as a new paint job to suggest rust accumulated during his incarceration and exile at the bottom of the ocean.

depending on how that blade lined up to camera. Whenever you saw it on the side, you got the full-on 3D shaded look; the closer you got to looking at it edge-on, the more it vanished and looked like a thin line.”

Reed Man uses his razor edges to saw into a cylinder holding the Allspark shard, then steals the object, running out of the facility as soldiers fire on him. Meanwhile, Decepticons disguised aboard a freighter ship dive into the North Atlantic to recover Megatron from the ocean floor. The underwater scene was comprised of all-CG shots created by ILM. Compositing lead Francois Lambert and his group used a custom underwater plug-in that automatically created haze and murky depth effects, based on the position of light sources. “This plug-in was for Shake,” said compositing supervisor Nelson Sepulveda, “and it was based on algorithms that we got out of Siggraph papers analyzing properties of liquids, from sea water to champagne, and how light behaves in them. Using this plug-in, we could take CG images and reproduce what they would look like inside any particular liquid. It gave us a terrific look.” Compositors refined the results by adding ambient lighting and layers of particulate matter.

In the all-CG sequence that follows, the revived Megatron meets with Fallen, supine on a large throne aboard the Nemesis spacecraft — an environment designed by ILM art directors Alex Jaeger and Yanick Dusseault. A major character in the first Transformers, Megatron went through a significant redesign and remodeling. “We get a lot closer to Megatron in this movie,” said Dave Fogler. “That, plus prepping him for IMAX, meant we had to do a complete reworking of that character. Megatron had new panels and legs that had treads running through them, which ended up being quite a difficult rigging problem. As we were starting to see him rendered, we realized that his legs were coming out huge, out of proportion with his body. We had to design a system where, shot by shot, we could adjust the thickness of his legs, without it affecting all the other animation of the tracks and the treads. His paint job was different as well, the idea being that he would have a lot of rust on him after being at the bottom of the ocean for so long. If you compare the two Megatrons, the new one has a lot more detail and texture.”



At the warehouse, Megatron orders Sam strapped to a table and probed by a crab-bot searching for crucial data stored inside the teenager’s head. ILM gave Michael Bay complete freedom of camera movement in covering the examination by sending a team to the location to shoot stills from eight different positions, both high and low. The digimatte team stitched those stills together to re-create the warehouse set, and Bay then choreographed his shots, flying the virtual camera through the space as he wished.

Compositing lead Tory Mercer oversaw the synthetic Nemesis shot, which was sweetened with layers of practical elements. “Tory used a huge number of 2D photographic elements that had been shot at Kerner Optical,” said Nelson Sepulveda. “We used a lot of water elements, mist, particulates and lens flares. You don’t see it in the projection because it gets cut off, but we even added the vignettes you get on the corners of the image when you’re shooting through a real camera. If you look at those images in their entirety, they look like photography.”

Both the underwater and Nemesis sequences took advantage of a new virtual camera system, developed by ILM's motion capture crew, that enabled Michael Bay to compose the all-CG shots as if he were in a live-action environment with actors. "Michael Bay comes from a background of being behind the camera," said Scott Benza, "and so he is very specific about camera work, very hands-on. But in shots with all-digital environments, all he could do was describe the camera to us. We had to interpret what he said, and sometimes we didn't get it exactly right. So we made use of this virtual camera, which had a display on it that allowed Michael to look into a CG environment. We'd load our 3D environment into Zeno, our proprietary environment package, and he could operate this virtual camera to create camera moves within that environment on the fly. As he moved this device, it would move like a camera through the 3D environment. Using controls on the virtual camera, it could simulate Steadicam moves, hand-held, whatever. Focal lengths could be adjusted. Moves could be multiplied by any factor, so a small move could be made into a large crane move. He just strapped this thing on and started running around doing shots within minutes. And all of those moves were recorded, so we could plug them into our shots. Sometimes there were artifacts in the movements, so we would have to refine them; but it was great to know that we had exactly the move he wanted to start from."

Due to the size of some of the CG environments, real-time movement within them was often not possible. To get around the problem, ILM created lighter versions of the environments, still retaining enough detail to enable Bay to compose shots and get a good sense of spatial relationships. Low-resolution versions of the CG characters were also on display on the virtual camera screen. “We maintained as much detail in the CG characters as we possibly could to help Michael as he composed shots,” said Jeff White. “We had done a couple of animation passes by that point, and we had that animation loaded in there. So, much like he would do on a set, he would say ‘action,’ and we’d hit ‘play,’ and the characters would move and then he could move with them. It was very helpful, and it allowed Michael to work with all-CG shots in a very hands-on way.”

Back on planet earth, a small Decepticon disguised as a radio-control toy truck searches Mikaela’s chop shop for the Allspark cube splinter that Sam has given her for safekeeping. None of Digital Domain’s robots in *Transformers 2* went through a more thorough and changing character development than ‘Wheelie.’ “They changed voice actors for Wheelie about halfway through production,” explained Matthew Butler, “and since the voice drives the character, that meant that the character changed. He started off more of a lovable character, a little sad and pathetic; and then he became more of a brash, Jersey-accented tough guy — a really rude, nasty, horny little devil.”

Wheelie’s look changed with the evolution in his personality. “Starting out, Wheelie was more sinister looking,” commented Dan Taylor. “So we needed to soften him up from a modeling and design standpoint. He had these big scary hands initially, for example, and we made them a bit rounder, smaller and cuter. We couldn’t make him look too soft or friendly, though. He was still a Decepticon, even if he was a funny Decepticon.”



The Autobot hero of the first *Transformers*, Optimus Prime, dies in a brutal battle with Megatron and other Decepticons in a forest, one of the film’s two signature action sequences. Armed with approved animatics, Scott Farrar and animation supervisor Scott Benza spent three days in New Mexico, shooting specific plates for the forest fight, in IMAX format, while the ILM digimatte team shot stills that would enable them to tile backgrounds, if necessary.



When Mikaela spots Wheelie cracking into the chop shop safe where she has hidden the Allspark splinter she chases him down and stuffs him into a case. On-set crews had puppeteered props to suggest Wheelie's interactions with the environment, such as when he picks up cigar boxes, searching for the splinter. "They had put the cigar boxes on sticks and moved them on the set," recalled Lou Pecora, "and our Wheelie animation was locked to that timing. But, of course, Michael didn't want to have his hands tied by that, and neither did we. So we got good coverage of that set with a lot of stills, which allowed us to rebuild those plates. It was a good thing we did, because otherwise we would still be working on those shots. It wasn't just a matter of getting rid of the stick holding the boxes — it was also removing the shadows cast by the stick, the boxes, the operator, all of that."

Though Michael Bay was determined to use the IMAX plates for the forest fight, rather than virtual environments, in some cases ILM extended those plates so animators could pan off of them to improve the framing of a shot. To better integrate the robots into the forest location, ILM added interactive effects, augmenting practical explosions and other effects executed by special effects supervisor John Frazier. To upgrade its existing effects library so that it would hold up to IMAX resolution, ILM shot new elements of dust, sparks and smoke on Vistavision at Kerner Optical, then scanned them at 6K resolution.

Mikaela takes Wheelie with her when she flies out to visit Sam at the university, entering his dorm room only to discover him on the bed, locked in a kiss with a seductive young coed named Alice (Isabel Lucas) — actually a Decepticon disguised in human form. In one of Digital Domain's most challenging shots, Alice transforms from girl to fully mechanical 'Pretender' robot. "The shot starts close on her," commented Matthew Butler, "and her face begins to segment and peel back to reveal nasty metal Medusa-like hair structures inside a mechanical face. Then the whole body unzips in a very complicated arrangement of panels to reveal the robot. It was incredibly complex, going from a fully real, organic, clothed human character, to a CG version of that human character — which was roto-captured and keyframe animated — to a completely procedural complex array of mechanical armatures and plates that tumble and rotate to form the inner robot. There were a lot of mixed software and disciplines involved in that."



Decepticons destroy an aircraft carrier at sea, a CG sequence that took ILM nine months to complete. An ILM crew accompanied Michael Bay aboard the USS John C. Stennis to capture reference photographs and textures. Modelers then built everything on the doomed ship's deck in CG, including F-18 Hornets, Blackhawk helicopters, missile carts and deck debris. ILM crewmembers in costume, filmed on ILM's motion capture stage, portrayed seamen. Explosions were photographed on a 1/20-scale model of the ship's interior hull at Kerner Optical, and were augmented with hundreds of rigid simulations to generate exploding hardware and falling debris.

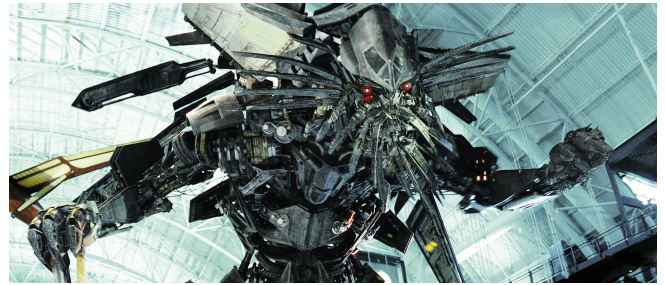
DD artists first created an Alice model from a cyberscan of Isabel Lucas, then rigged that geometry. "We spent a couple of weeks finessing a rotomation of the plates," said Paul George Palop, "based on our geometry and rig. We had done the cyberscan without a dress, so we had to model the dress and rig that as well, running a cloth simulation to closely match what the real dress was doing on the girl. So far, all of that was very straightforward. Then, for the actual transformation, we exported our Alice geometry cache into Houdini and created a randomized point cloud over locations that correlated to the real surface. So we had a distribution of little tiles all over the anatomy of Alice, which opened and moved and rotated. We could control what the size of those would be, what their

orientation would be, how they would move. Then we had to figure out how to make the tiles look good. Re-projection wouldn't have been enough to add realism to the rendering of the tiles, because the lighting information would change as they moved, and we couldn't do that just using the lighting from the plate. So we had to do CG lighting and HDR lighting and all kinds of ray-traced passes to give the compositor final control."

One of the difficulties in executing the transition from Alice to the Pretender robot was that the actress had a much smaller head than what would look threatening in robot form. "To some degree," said Dan Taylor, "we had to fit the robot inside this actress' body and head, but her head was really tiny. So, toward the end of production, we started playing around with her hair, making it part of the robot head structures. Once we took all of that hair and made it alive with Medusa snakes in it, it visually expanded the size of her head, and that character became more aggressive and mean."

After being chased across campus by the Alice robot, Sam is captured by the Decepticons, and then rescued by the Autobots, along with Mikaela and his roommate, Leo (Ramon Rodriguez). As the trio races to safety, Optimus fights Megatron and three other Decepticons in a forest. The forest fight was one of the film's two signature action sequences, overseen by sequence supervisors Robert Hoffmeister and Polly Ing and choreographed in animatics created by Scott Benza, Rick O'Connor and lead animator Greg Towner. "Ninety percent of the previz had already been done by Michael's artists at Bay Films," noted Benza. "But there were a couple of key sequences that hadn't been prevized to the level that they needed to be, because they involved fight choreography. We learned in the first film that elaborate fight choreography has to be fleshed out in previz before you shoot backgrounds. So we took the initiative and started doing previz of this battle between Optimus and the Decepticons in the forest. We spent about two months designing a three-minute fight, coming up with as many ideas as we could."

Although the previz work was done before new models had been completed, the animators were able to work with robot models from the first movie. Animators also had a good sense of the setting of the fight, as production had supplied them with location photographs from the New Mexico forest where Bay planned to shoot the scene. "From the photographs," said Benza, "we knew there was a clearing and that there were landmark trees, and that helped to give us a sense of the geography the fight would take place in." Much of the fight action was choreographed by Greg Towner, a student of martial arts. "Greg has a knack for coming up with crazy fight moves, and so he became our resident fight expert on the film. He had done quite a few fight scenes in the first movie, and Michael was really happy with how those came out. For this fight, he introduced a lot of martial arts moves, taking into consideration the capabilities of the robots. There were limitations to what the robots could do, based on their design."



To uncover the meaning of the bizarre alien symbols he has been envisioning, Sam confronts an elderly Decepticon, named Jetfire, who has been in inert hiding at an aeronautical display at the Smithsonian for many years. To suggest advanced age, ILM modelers built Jetfire with a metallic beard and added small hoses, hinges and valves to his face. Jetfire body structures included retro-looking parts, such as cogwheels and fans driven by leather belts. Texture maps simulating dirt, grease and grime enhanced the aged effect.

Armed with approved animatics, Benza and Scott Farrar spent three days at an Indian reservation near Alamogordo, New Mexico, shooting specific plates for the forest fight — in IMAX — as Bay shot first unit with the actors. ILM's digimatte team was also on location to shoot stills, which would enable them to tile backgrounds if the plates proved unsatisfactory. "In the end," related Benza, "Michael used all the footage that was shot with the IMAX cameras. He was touting the sequence as one of the first involving CG characters shot on real IMAX cameras; and so to have a few shots in there that were all digital would have gone against what he wanted the sequence to be."

After the forest footage had been shot, Bay delivered the plates to Benza, allowing him to take a first pass at editing the fight scene together, based on the previz. "That experience gave me all-new respect for editors," Benza said. "If you're working in Maya, you can just come up with whatever camera move you want; but when you're working with physical plates, there are limitations to what those cameras can shoot and how fast they can move and how long they can run, et cetera. After I took a crack at it, Michael's editors conformed the sequence to what he had in mind. A lot of editing choices I made ended up in the movie, though, which was great."

Though Bay was determined to use the IMAX plates for the forest fight, rather than virtual environments, in some cases ILM animators panned off the plates to improve the framing of a shot. "These robots are really big," said Jeff White, "30 to 100 feet tall. Out on location, everyone tried their best to represent that by sticking a character's head on window-washer poles; but they were still shooting empty plates and they didn't know exactly where the characters were going to be. So, for this and other sequences, we enabled the animators to pan off the background plate in order to make the character action work better; and then our environments department would extend the plate. That really freed the animators. Rather than be stuck with awkward timings or movements because they were trying to pack robot animation into plates, they could pan off the plate and create moves that really worked. We also let our animators do some pretty significant re-times to the plates."

To better integrate the robots into the forest location, ILM added interactive effects, augmenting the practical explosions and other effects executed by special effects supervisor John Frazier. "Our existing library didn't have elements that were sufficiently high-resolution for IMAX," said Scott Farrar. "So we had to go out and shoot all of these greenscreen and bluescreen elements — dust and



Jetfire transports Sam and his companions to Egypt to search for an ancient matrix key that will unlock a powerful alien energy source. A corollary to Michael Bay's edict that the robots always be well illuminated was his preference that they look crisp and sharp in shots, without the softening effect of too much motion blur or haze, even in settings or situations that might demand it. To that end, Scott Farrar developed formulations for reducing motion blur, and encouraged judicious use of atmospheric effects.



NE.T troops and their Autobot allies prepare for battle with Decepticons in the Egyptian desert. Scenes featuring

sparks and so forth — things that we've had for years that just weren't good enough for IMAX resolution." Robert Hoffmeister shot the new elements on Vistavision at Kerner Optical, then scanned them at 6K resolution.

many CG robots benefited from a multiple-resolution process – new to the film – in which each robot character was set up with five to seven different resolutions, ranging from very high to very low. The setup enabled ILM animators to work on the detail of one high-resolution character in a scene, while all the others remained at low-resolution, significantly reducing save times.

The model and paint crew also worked to accommodate the higher IMAX resolution, adding layers of detail — such as dings and other fight damage — to the robots, most especially Optimus. "Our work I'm most proud of in this movie is the damage on Optimus in the forest fight," said Dave Fogler. "We needed to show the progression of the damage on him from beginning to end. Aaron Wilson created five stages of Optimus damage as separate, distinct texture files, essentially modeling with paint, through displacement. He did an amazing job of using opacity maps to make holes in metal panels and displacing the metal so it looked torn and chunky along the edges. Also, because it's in a forest and Optimus is falling on the ground, Michael had the idea that he should have chunks of sod on his head, like a football player will have in his helmet after a game. By the end, he's just covered in muck and all of his panels are torn up."

Sam watches in horror as Optimus is killed in the fight. With the death of the last Prime, Fallen returns to earth to lead a full-scale attack on the planet and to extract information regarding the location of a vital energy source from Sam's brain. Arriving on earth in what looks like a meteor shower, the Decepticons strike and then destroy an aircraft carrier at sea. The sequence took nine months to complete and represented some of ILM's most challenging work on the film. Alex Jaeger and Yanick Dusseault produced extensive artwork to define shots, which featured many digital assets in addition to the rampaging robots. To capture authentic textures, an ILM crew accompanied Michael Bay aboard the USS John C. Stennis on a sea run. Based on those reference photographs, ILM built everything on the ship's deck in CG, including F-18 Hornets, Blackhawk helicopters, missile carts and deck debris, all detailed in paint work by viewpainter John Goodson. ILM crew members, shot on ILM's motion capture stage in costume, portrayed the deck soldiers. Explosions were photographed on a 1/20-scale model of the ship's damaged interior hull at Kerner Optical, and creature TDs Karin Cooper, John Teska, Chris Evans and Michael Balog ran hundreds of rigid simulations for all the exploding hardware and falling debris.

The scale of the sinking carrier required a massive water simulation that took days to complete, run by 3D sequence supervisor Willi Geiger. The simulation included many layers of water, spray and foam that had to be run in succession and then rendered using a technique created by production TD Frank Losasso Petterson, which combined multiple particle simulations into a single volume grid. The system then used volume rendering shaders to achieve much greater detail than was possible with traditional particle simulations. Final composites were assembled by compositing sequence



Decepticons drop from the sky like blazing meteors, crash-landing at the desert site, ready for battle. Michael Bay and his crews captured ground footage near the pyramids of Giza over the course of several days. Uncertain as to whether the production would secure permission to shoot

supervisor Ben O'Brien, composers David Feurer and Scott YOUNKIN, and Sabre artists Alex Tropieć and Dean Yurke, all of whom added real spray, foam, fire and ocean surface elements whenever possible to augment the CG work. Carrier lighting and look development was done by production TDs Scott Prior and Akira Orikasa.

aerial plates of the ancient landmarks, ILM crews prepared to rebuild all of Giza digitally using stills shot from every side of the Great Pyramid – a task the team was spared when the filmmakers obtained eleventh-hour approval for the aerial shoot.

To learn the meaning of the alien symbols he has been envisioning since first touching the Allspark splinter, Sam meets with Agent Simmons (John Turturro) — blog name, RoboWarrior — who leads a mission at the Smithsonian to uncover old Decepticons who have been hiding on earth for many years. There, the elderly Jetfire transforms from an old SR-71 spy plane on display. Modeler Rene Garcia built the character with a metallic beard — as illustrated in the production artwork — and added small hoses, hinges and valves to his face. Jetfire body structures were designed to suggest his advanced age. “We made a separate parts library for Jetfire,” said Dave Fogler, “with very retro-looking parts, like cog wheels and fans driven by leather belts. Jetfire’s surfaces are also dirty and rusty; so we had to come up with many texture maps for dirt, grease and grime. We also conveyed his age by giving him a cane made of landing gear and having him drip oil everywhere.”

As the robot with the most dialogue and closeups, Jetfire required some of the most delicate character animation ILM would be called upon to deliver for the movie. “We had to do a lot of facial performance for him,” said Scott Benza, “and we had to make him a geriatric character in terms of his body movement. We started by compiling reference of actors we thought were similar to this character. The most helpful reference was Burgess Meredith from the Rocky movies. He talked out of the side of his mouth, and one side of his face was squinted up a bit — and that asymmetry was something we did in Jetfire to sell the fact that he was a weathered veteran. We also had him hunched over a lot of the time, leaning on his cane. If we found ourselves with a few seconds where we were looking for something for him to do, we would have him reach back and adjust his back, as if it hurt.”

Within the Smithsonian, ILM tweaked their character lighting in CG, just as Michael Bay would do on set. “Jetfire is over 50 feet tall,” Scott Farrar noted, “so if you were lighting him in the real world, you’d have maybe a 10K or 20K light up on a scissor lift, and that might light his head and shoulder — but it wouldn’t light his whole body because of fall-off. So you’d add other lights. We did the same thing in the CG lighting. In the end, I think we had 41 lights on Jetfire, so you would see a pool of blue light on his shoulder, or a pool of warm light on his leg.”

Jetfire teleports Sam, Mikaela, Simmons and Leo to Egypt, where the Decepticons plan to uncover a long-hidden machine that will destroy the sun. The



Construction vehicles transform into Devastator, the largest computer model ever built at ILM, comprised of some 52,000 pieces of geometry. To facilitate storage of the huge IMAX-resolution character, ILM separated the final

desert becomes the setting of an epic final battle — another IMAX sequence — between the Decepticons, Autobots and NE.T. the latter having been instructed by Sam to drop Optimus' body there, in hopes that he might be revived. On route to the location, NE.T soldiers push government meddler Galloway (John Benjamin Hickey) out the plane's cargo door, with a parachute, so that they might fulfill their mission. The shot of Galloway at the open plane door was one of the very few bluescreen shots in *Transformers 2*. "These days, I rely a lot on roto artists," noted Scott Farrar, "because our roto tools and talent are incomparable. The amount of roto in practically every shot in this movie is pretty astounding. Our roto team is led by Amy Shepard, and they are really the unsung heroes of this movie."

~~Devastator climbs a pyramid in which an ancient sun-destroying machine is buried, smashing blocks as he ascends. ILM built a physically accurate pyramid and executed its destruction via a new simulation that dynamically fractured blocks as they were impacted. A second simulation created attendant dust and particulate debris.~~

As all sides prepare for battle in the desert, a heavily tattooed Starscream shoots down from the sky, landing on one of the Giza pyramids. The application of tattoos on Starscream — who had appeared in the original film — was one of the most comprehensive and difficult robot upgrades realized for the sequel. "We had to actually go into an existing texture setup," explained Dave Fogler, "and layer these tattoos on top of that, as if etching into metal. He was covered with these things, and it was a neat look — but it was very tricky to pull off."

Starscream and other computer generated characters were integrated into plates Bay and his crews had shot on location at Giza, at the base of the pyramids, over the course of several days. "Our worry at that point was that we still didn't have approval to get aerial plates," recalled Scott Farrar, "so we thought we might have to rebuild the whole thing, especially from the air. We were committed to doing that, even though it was going to be really difficult — but they finally got the approval to shoot plates with the helicopters. So we had motion picture film shot from up high, and then we also shot stills from all sides of the main pyramid so we could fabricate just about anything we needed."



Rigid body dynamics simulations provided large-scale robot destruction, amplifying explosions and other live-action mayhem created by John Frazier's special effects crew. To create generic robot debris upon impacts, ILM used a library of CG parts such as gauges, wheels, springs and cogs, and combined them with actual pieces off the afflicted robot, running a rigid simulation to sever those pieces as the robot was hit.

Rigid body dynamics simulations provided large-scale robot destruction, and amplified the explosions and other live-action mayhem created by John Frazier's special effects crew. "We'd done some simulations for robot destruction in the first film," observed Jeff White, "but we really expanded it for this one because the end of the movie is a full-on battle. It was really important to Michael that every time robots made contact there would be some result. We had a library of internal parts to work with — gauges and wheels and springs and cogs — and we'd bring those into the scene and then combine them with pieces that were actually from the character, running a rigid simulation of those pieces breaking off as the robot is hit."

Six large construction vehicles arrive on scene and join together to transform into the massive Devastator, the largest computer model ever built at ILM. “Optimus Prime in the first movie was the largest and most complicated model ILM had ever done up to that time,” noted Wayne Billheimer. “But Devastator was essentially six Optimus Primes.”

The completed Devastator model was comprised of more than 52,000 pieces of individual, ‘animatable’ geometry, which broke down to 12.5 million polygons. “Devastator was an exercise in brute force complexity,” said Dave Fogler. “It was like taking seven of our already complex and hard-to-render robots and stuffing them into one.” The ILM crew first modeled and painted the robots and construction vehicles that comprised Devastator. All of that data was then pumped into the parts library system, which Rene Garcia used to assemble the model. Viewpainters Aaron Wilson and Leigh Barbier oversaw the texturing of the thousands of parts. “All things considered, it was a pretty efficient way to do it. The biggest walls we hit were just technical ones, the physical limitations of our storage and render abilities.” For storage and rendering purposes, the final Devastator was separated into six models — one for each arm, one for each leg, the torso and the head. “The only way we could deal with storing this huge model was by breaking it up that way. Adding insult to injury were the IMAX shots, which were such high resolution, they took a very long time to render.”

“Devastator was so huge,” Scott Benza elaborated, “that working with him in high-rez just ground our machines to a halt. So we were able to work on just one high-rez limb at a time, or just his head. One of the cool things about our multi-resolution pipeline, though, was that we could work with the model in a super low-resolution form, in real time, which is unheard of for a character made up of so many pieces and separate parts. That created huge efficiencies for the animators.”

Lead digital artist Kaori Ogino rigged Devastator.

“The rigging had to be pretty elaborate to manage all 50,000 pieces of geometry,” stated Benza. “And with that many pieces, it was inevitable that there would

be a lot of interpenetration. So there was a lot of work put into the rigging to avoid collisions. It was set up in a hierarchy, so certain pieces would automatically move when he lifted his arm, for example. We did that with all the characters, but even more so with Devastator, just because of the large number of pieces he had. The rigging also had to accommodate functioning cables that ran through his body.” Animation lead Shawn Kelly oversaw Devastator animation, and designed the character’s assembly from the separate construction vehicles. “Shawn came up with the whole concept of how Devastator would form, and it wound up in the film almost exactly as he designed it.” Simulations run on top of keyframe and procedural animation created secondary animation effects.



After being revived by the dust of the matrix key, Optimus engages Fallen in a final battle that ends in the Decepticon’s death. One of the last sequences turned over to ILM, the fight was choreographed in animatics by Scott Benza and lead animators Greg Towner and Rick O’Connor after location backgrounds had already been shot in Luxor, Egypt, forcing the animators to devise fight choreography that would fit the existing plates.

Devastator climbs the pyramid in which the sun-destroying machine is hidden, smashing and crushing its ancient blocks as he ascends. Backgrounds for the action were sometimes IMAX aerial plates, other times high-resolution synthetic environments. “The Devastator sequence was all rendered up at 4K,” said Farrar. “We actually manufactured the plate in some cases, from stills we had shot on location. Because of the high resolution, one of these shots could take up to 72 hours per frame to render — and we haven’t seen those kinds of render times in a while.” Due to the long waits between renders, it was crucial that the effects artists perfect the lighting in the shots while working in lower resolution. “We worked at low-rez for a long time before we kicked it up to high-rez. They’d ask if I was happy with the lighting, and I’d cross my fingers and say, ‘Okay,’ — and then I wouldn’t see the shot again for four or five days. There were long shots, too, some of them 20 or 30 seconds long.”

For pyramid destruction, digital artist Christopher Horvath built a physically accurate pyramid from individual components. Animators animated Devastator climbing atop that pyramid model, and that animation drove pyramid destruction.

“Christopher Horvath wrote a simulation engine from the ground up that could simulate hundreds of thousands of pyramid pieces,” explained Jeff White, “which was far larger than any rigid simulation we’d ever done. He could not only simulate all those pieces — with collisions and all the other normal properties — he was also able to make the pyramid blocks fracture dynamically as they were hit. So Christopher would bring in the animation and run this block destruction simulation. Then, we ran a simulation for the dust and small particulate debris that comes off of them as they get knocked down. For that, John Hansen, Tim Fortenberry and Joakim Arnessen ran full fluid simulations for our smoke renderers, which gave us incredible levels of detail. So there were two levels of difficult and complicated sims.”

Sam brings Optimus back to life through the power of matrix dust — the remains of the key to the sun-destroying machine — who then engages Fallen in a final battle, another fight sequence choreographed by Scott Benza, Greg Towner and Rick O’Connor. *Transformers: Revenge of the Fallen* concludes with Fallen’s death and world peace restored — for now. It is far from the end for the movie franchise, however, whose future was secured when the Transformers sequel broke boxoffice records everywhere. The film also broke ILM’s records for size of models, complexity of simulations, and many other aspects of CG shot production. “With the IMAX and everything else,” concluded Scott Farrar, “this movie was much bigger in scope and scale, overall, than the first one. It was truly epic, like a combination of *Ben-Hur* and *Apocalypse Now*.”



*On the verge of death after a massive explosion during the desert battle, Sam appears to travel to an alien robot world – a stylized synthetic environment rendered by ILM – where a gathering of Autobot elders encourages him to survive. The film ends with Sam regaining consciousness and reuniting with Mikaela, his parents and his Autobot protectors, all at peace until the next Transformers film – a third entry all but assured by the smashing success of *Transformers: Revenge of the Fallen*.*

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